ELEKTOR ELECTRONICS

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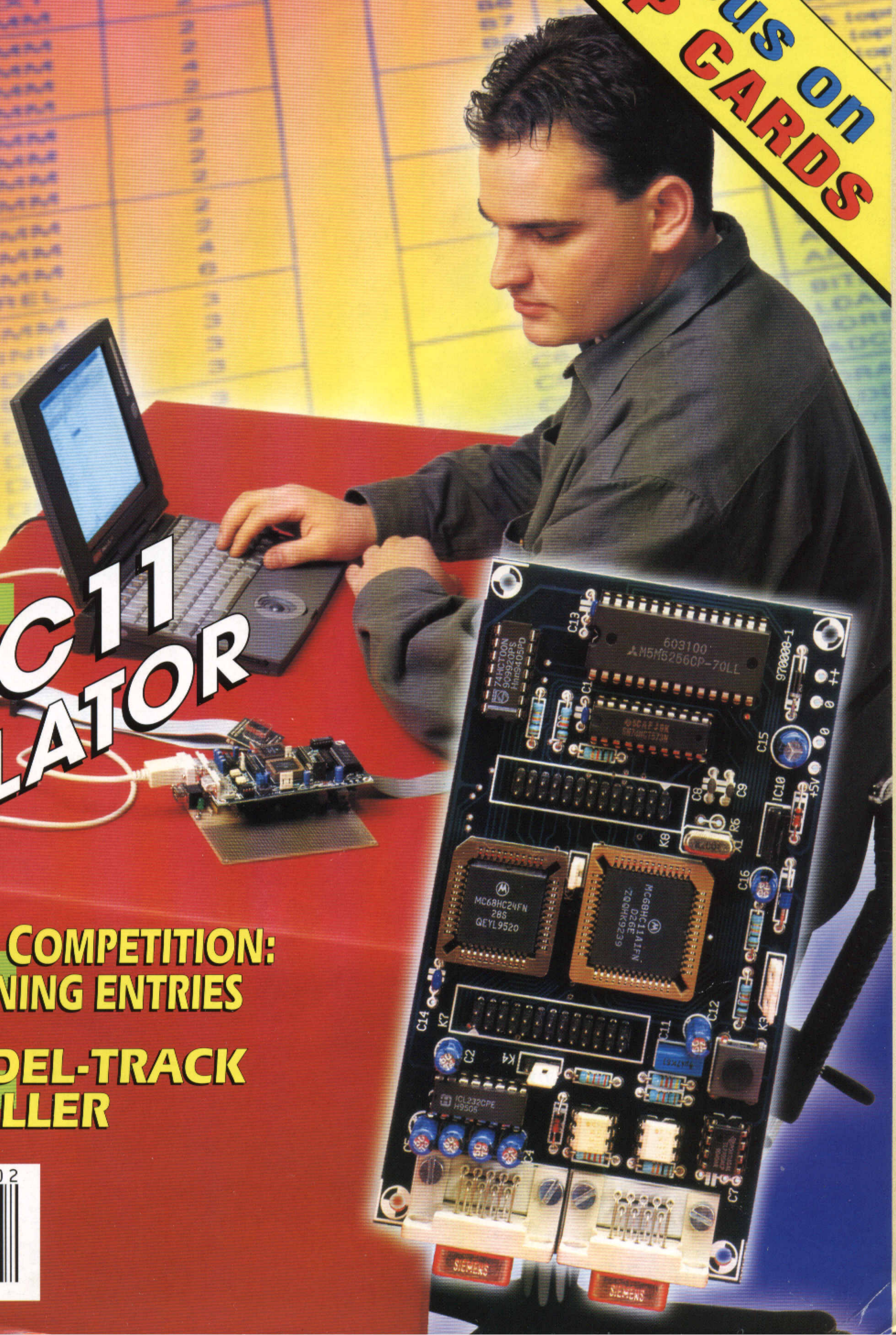
Focus on CHIP CARDS



68HC11 EMULATOR

SOFTWARE COMPETITION: MORE WINNING ENTRIES

PIC MODEL-TRACK CONTROLLER

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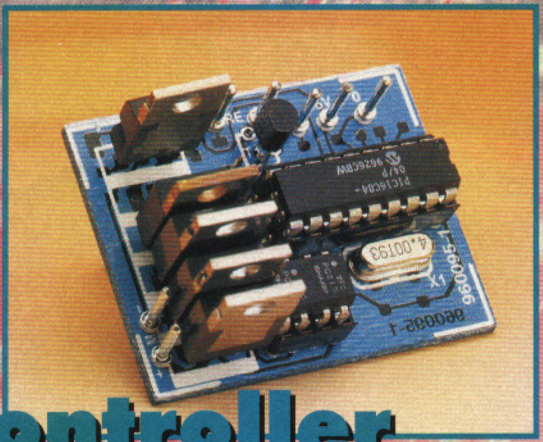

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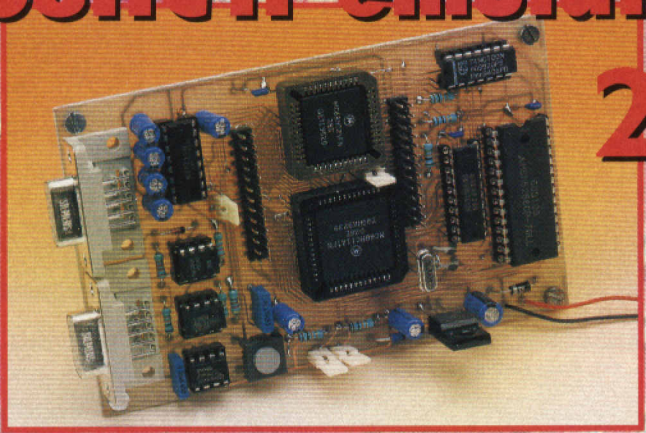

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ELECTRONICS NOW AND TOMORROW

In a short series of articles, ending this month, we will endeavour to present a broad overview of the direction electronics may be going during the last few years of this century. During the writing of the series, it was borne in mind that many 'promising developments' have failed to make it over the past ten years or so. One only has to think of the videophone (or picturephone), the digital audio tape (DAT) system, the digital compact cassette (DCC), the Series 2000 video recorder, the Betamax video recorder, and the mini disc system. On the other hand, the thermionic valve (or electron tube) and radio are making a comeback, while the compact disc (CD) has been a great success, although its popularity is also waning now.

COMPONENTS.

A new capacitor

The capacitor is one of the oldest types of component used in electronics engineering. The large Leyden jars which scientists used at the beginning of the 19th century to investigate the nature of electrostatics are displayed in most technical/science museums. Since those early days, the structure of the capacitor has remained basically unchanged. It comprises two metal outer layers sandwiching a non-conductive inner layer – the dielectric – in which the electrical energy is stored. Nowadays, capacitors are a typical mass-produced passive electrical component. The world market for capacitors is valued at about $ 7 billion.

Today, capacitors are expected to meet a number of requirements. Firstly, its overall dimensions for a given capacitance are important. Secondly, the value of its capacitance must be stable with fluctuations in temperature, frequency, and applied voltage. Thirdly, in many applications, its converted power dissipation is also important.

So far there has been no one type of capacitor able to meet all these demands. Now, however, Siemens researchers have struck out in a completely different direction. They have applied to the manufacture of capacitors essentially the same silicon processing procedures already familiar from semiconductor manufacture. Electrochemical etching of the silicon crystal produces a honeycomb structure with individual cells, rectangular in shape, 165 μm deep and 2 μm wide. The inside wall of each honeycomb cell forms the capacitor's first electrode. On to this, a silicon oxide/nitrite/oxide – ONO – sandwich structure is applied, forming the capacitor's dielectric. And on to this, a polysilicon layer is deposited, forming its second electrode.

Compared with the flat silicon surface, this honeycomb structure increases the surface area available for capacitor purposes by a factor of no less than 85, which means that high capacitance values can now be attained with relatively small dimensions. All stages in this manufacturing process are already standard procedure in semiconductor manufacture, which means that in series production a capacitor made in this way will not be appreciably more expensive than a typical discrete semiconductor. When it comes to technical specifications, the new capacitor outperforms conventional types in virtually all aspects, in particular its permissible operating temperature, its stability, and its power dissipation. Its performance data are superior to the best capacitors made on a polymer basis.

The high-frequency properties of early laboratory samples are being examined to determine their suitability for the h.f. levels of mobile telephones.

New CMOS technology

NEC Corporation and the Microelectronics Group at Lucent Technologies Inc. have commenced research and development of an 0.18 μm CMOS device process technology that will enable manufacturing of ultra-large scale integrated circuits (ULSIs) two generations ahead of today's semiconductor products. These 'systems on a chip' will enable smaller, smarter and faster devices that make visions of the 21st century a reality.

Battery of the future?

An exciting development that is taking place in the battery world is the fuel cell. Fuel cells, invented by Sir William Grove in 1839, are undoubtedly the battery technology of the future. Until now they were, unfortunately, very expensive to produce. A break-through by Canadian manufacturers Ballard Power Systems has been to reduce the amount of catalyst needed in these cells. The catalysts is required to control the reaction between the hydrogen and the oxygen in a cell. Since the catalyst is platinum, Ballard's innovation reduces the costs of the cells considerably.

Fuel cells work by the reverse of electrolysis. If an electric current is run through water, its constituent elements – hydrogen and oxygen – will bubble out. Running the process backwards by combining hydrogen and oxygen generates electricity. This is significantly different from most types of battery. Though batteries also work by reverse electrolysis, they have to be recharged with electricity – a lengthy process. A fuel cell has no need for the weighty metals used by batteries, making it much lighter. And it needs only a quick recharge with hydrogen. Environmentalists like fuel cells, too, because they produce electricity with only water as their exhaust.

THE INTERNET

The sad thing about the Internet is that it has been used for a long time to disseminate illegal material, such as child pornography and sedition. But now two leading industry trade associations in Britain have put in a proposal, backed by the government, for a self-regulatory system to tackle such material.

Internet Services Providers's Association and Linx (London Internet Exchange) have joined forces with the newly established safety net foundation to

A Book for your Letter

The work of Marconi in proving that radio waves do not necessarily travel in straight lines, which resulted in today's world-wide radio communications networks, engendered a fiery interest in many people to become radio amateurs. These people were the forerunners of what are now called 'experimentalist' and home constructor'. This army of amateur constructors grew enormously with the advent of radio broadcasting in the 1920s. It is hard to imagine today, but then there was a widespread feeling that it was extravagant and almost decadent to buy a ready-made radio receiver. This feeling was taken advantage of by various manufacturers who started to market kits of parts. These kits proved to be enormously popular; for example, Cossor Radio (now part of Raytheon) in the period 1927–1936 sold more than 750,000 kits of their popular radio receivers.

After the Second World War, home construction really took off since finished electronic products were either not available or too dear, but vast quantities of electronic parts, surplus to the armed forces' requirements, flooded the market.

Home electronic construction reached a peak during the 1970s and then started to tail off. This was partly due to the fact that manufacturers had begun to realize that there was a vast consumer electronics market waiting to be satisfied. Other reasons were changes in the social life of most people in the western world, resulting from a better standard of living.

However, there are, no doubt, other reasons why home electronic construction is declining although the interest in, and use of, electronics is growing. If you feel that you can point to some of these reasons, write to Elektor Electronics (Publishing), P O Box 1414, Dorchester DT2 8YH, England, outlining them in no more than 250 words. The five letters that in our opinion most clearly set out additional reasons will be published in this magazine and their writers will receive a free book from our library.

Transformers for valves
A range of transformers specially designed to meet the needs of the resurgent valve market is available from Variable Voltage Technology Ltd. The new range, comprising mains transformers for h.t. circuits with or without filament windings, filament transformers, mains smoothing chokes, output transformers, and grid-coupling transformers, is manufactured to traditional requirements but with the use of modern methods and materials. They met the requirements of the EMC and low-voltage directives; CE marking is available where appropriate. Variable Voltage Technology Ltd, Unit 24 Samuel Whites Estate, Medina Road, Cowes, Isle of Wight, England PO31 7LP; telephone +44 (0)1983 280592; fax +44 (0)1983 280593.

take action on unlawful material on the net.

The proposals include a telephone hotline to which Internet users can report material they think is illegal along with 'blocking' software that censors sites from view, so that children can use the system unsupervised.

The proposals – called Safety Net – mean that any users of the Internet can ring a dedicated telephone number and report material they think is illegal. If the information originated in the UK, and is deemed to be against the law, the Safety Net will contact its Internet provider, who will contact the person who put the information on the network and ask that person to remove it.

Users are assured that "this is not a question of censoring legal material or free speech. The Internet has never been a legal vacuum. Responsible service providers want to see the law upheld. The core of the proposals is about dealing with materials that breaks our existing laws, especially where child pornography is concerned".

In a pioneering move, Cambridge City Council is publishing air-quality information on the Internet, providing open access to live scientific data to help town users and planners understand what's going on in their local environment.

The information will help the public plan journeys and town usage more effectively and help council and environmental planners address new government air-quality targets which must be achieved by 2005. It will also provide a powerful educational tool on environmental issues for the general public, and schools and colleges around the world.

IMAGE TECHNOLOGY

Digital cameras now on the market, or about to be launched, are getting cheap enough to be considered as alternative to 35 mm SLR cameras. It is satisfying to note that the manufacturers of these cameras are not falling into the same trap as so many CD-ROM producers: all good digital cameras come with software for the Apple Macintosh and IBM-derived PCs (not Acorn, though).

A fine example of a recently introduced digital camera is Agfa's ePhoto307 which retails at $599. This offers two resolution settings: 320×240 and 640×480. The lower setting is for on-screen applications (web pages, e-mail), and the higher for printed documents. Storage on these cameras is generally facilitated by a PCM-CIA memory card.

No doubt, these cameras will be further enhanced in the next few years – as well as become cheaper.

ELECTRONIC POLICE STATIONS

Britain's local police stations will be replaced by hole-in-the-wall video links or Internet connections, according to predictions from John Newing, Chief Constable of Derbyshire. Mr Newing, national police spokesman on technology, told an international policewomen's conference recently that over the next 15 years smaller police stations will be closed and some main ones would not be open at night.

TELEVISION

While Europe is prevaricating, as so often, over the future of digital television, the Americans have taken another big step to consolidating their hold on the technology. An agreement between broadcasters, computer manufacturers and makers of TV receivers will enable the Federal Communications Commission – FCC – to finalize plans for a high-definition format that puts the US well ahead of Europe and Japan.

It may not be good news for consumers, though, because there is not going to be the one standard we all hoped for. The television industry wanted a standard that in many ways is based on existing analogue technology. The film industry wanted a much more advanced standard with an aspect ratio of 2.4, a long cry from the present 1.33 – even PAL Plus with a ratio of 1.78 pales into insignificance. Engineers might ask "Why fix an aspect ratio?" since state-of-the-art technology allows each trans transmission to be preceded by a header specifying its shape.

Furthermore, the film industry wants to get rid of the 'interlaced' scanning of the TV picture (which should have happened 20 years ago) and replace it with 'progressive' scanning as used in computer monitors. As anybody who has compared his/her television picture with the images on the computer monitor knows, this gives a much better definition because there are twice as many lines. In a way, the new agreement is to the liking of the computer industry, because the TV makers dropped their demand for a single HDTV standard (this would have meant that computer monitors would have to be compatible with the interlaced scan format). Broadcasters will, if the agreement is approved by the FCC, be able to transmit digital video in either interlaced or progressive scan format.

COMPUTER SYSTEM MATCHES CCTV FILM WITH PHOTOGRAPHS

Four of Britain's police forces are testing a new computer system that matches film from closed-circuit televison (CCTV) cameras at the scenes of crime with police mugshots and material gathered by criminal intelligence. Known as Crimenet, the system was developed by the Police Foundation, a charity and police think-tank, working with British Aerospace and two suppliers of security cameras.

Crimenet will help the police to overcome the time-consuming task of trying to mach the images on CCTV film with thousands of mugshots. The new system takes the pictures from the CCTV film and compares them with a databank of convicted or suspected criminals. The criminals' features are turned into a geometric computer code and stored in an archive. Pictures from the scene of a crime are also turned into code and the computer sifts the two sets of detail for a match. The system can cope with identifying criminals who use disguises by comparing measurements such as height and weight, type of disguise, and unusual features such as the type of jewellery worn.

COMPUTER SYSTEM WILL HELP CHILDREN GIVE EVIDENCE

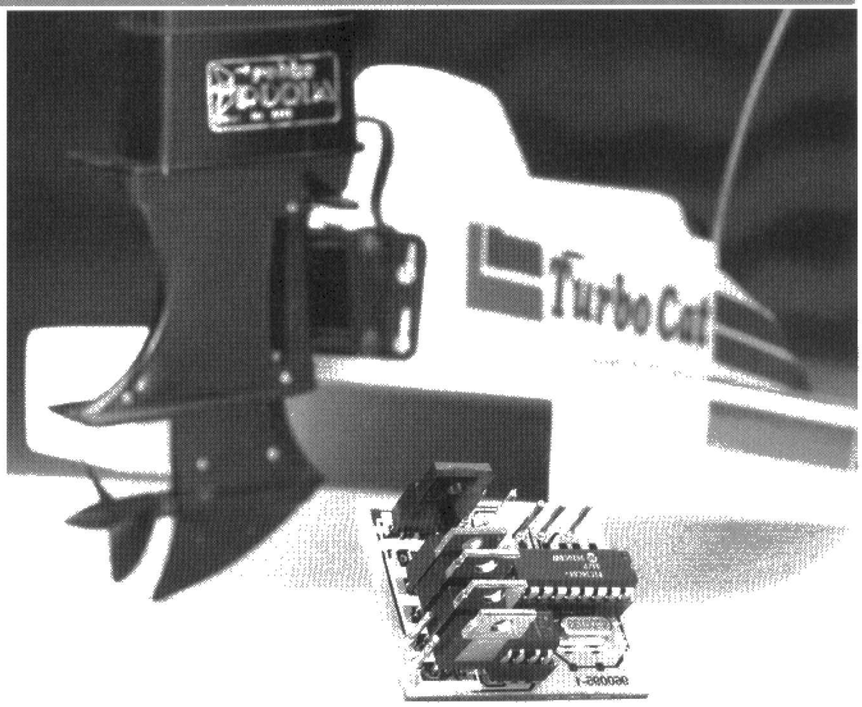
A computer program, the Macinterview system, funded by the Department of Health and developed in Britain by a team of psychologists, psychiatrists and computer researchers, could soon be saving children from the suffering caused through having to relive abuse experiences during interview.

It had been found that children find it difficult to talk about abuse and other severe emotional experiences to psychologists and police officers in a one-to-one situation. Children who have to appear in court as witnesses have even greater problems, even though video links are often used.

Macinterview uses images, sound, speech and video to take away the emphasis from the one-to-one relationship and make the computer an intermediary. It helps to build rapport and stores records of interviews. At the beginning of the interview, the child selects a representation of him/herself from a multi-ethnic display and then learns to drop facial expressions on to that figure to represent different emotions in different environments. The child also chooses representations of home and family and uses the range of facial expressions to represent feeling and emotions experienced with different people. This enables children to show who they have been with when they have experienced particular feelings. A range of pain sensations is also used to describe the sensations the child has experienced. Rachel Calam, a psychologist at the University of Manchester, and one of the development team, says: "The idea for the software stemmed from watching how well children interact with computers. At the time we were working on difficult suspected abuse cases and were very conscious that children felt they were being put on the spot and were uncomfortable in one-to-one interviews."

motor controller for R/C models

microprocessor-controlled



Model building is pretty popular among our readers, and circuits for this hobby are published from time to time. The true electronics enthusiast will object to the energy waste caused by the use of an adjustable resistor to control the speed of an electrically powered model. The circuit presented here provides nearly loss-free speed control thanks to the use of a microprocessor.

Design by
A. Voggeneder and A. Nader

Radio-controlled (R/C) modelling seems to fascinate many electronics enthusiasts. This technical hobby is a melting pot of many interesting disciplines, including mechanic engineering and electronics. Many 'modellers', and especially newcomers, start from largely pre-assembled models or kits which allow them to build a model boat, car or airplane without too much of a risk. All battery-powered models have one aspect in common: the speed control is based on a variable resistor which is operated by a servo motor. Anyone who has used such a model for some time will discover that the variable resistor may run pretty hot, which means that a lot of energy is wasted in the speed control. A shame, really, because the storage and retention of sufficient energy to power just about any vehicle is still one of the biggest problems in model building. Fortunately, there exists a much more efficient alternative. The present circuit demonstrates an intelligent and low-loss motor controller which may be built from relatively few parts. The result: one battery charge will allow the model to drive, fly or sail longer. Because the circuit is relatively easy to construct, improved efficiency does not come at high cost in this case. Moreover, the size and weight of the circuit are modest, which is an important aspect in this context.

A SEAMLESS TRANSITION

As a matter of course, the electronic motor controller was designed to comply with standards which are widely used in radio-controlled model building. After all, keeping to the conventions is the only way of making sure that the existing regulator may be replaced by its modern electronic counterpart. The mechanical speed regulators which are normally fitted in ready-made models are controlled by a servo motor. The servo, in turn, is controlled by pulse-width modulated signals supplied by the radio receiver installed in the model. The pulses that form the servo control signal have a width between 1 ms and 2 ms. In this

Technical specification

Supply voltage:	6 to 10 V
Supply current:	<5 mA
Max. output current:	40 A
Processor:	PIC16C84
Connection:	3-pin plug
Application:	model boat, car, plane
Versions:	unidirectional or bidirectional
Motor brake:	internal with unidirectional version
Thermal protection:	at 120°C

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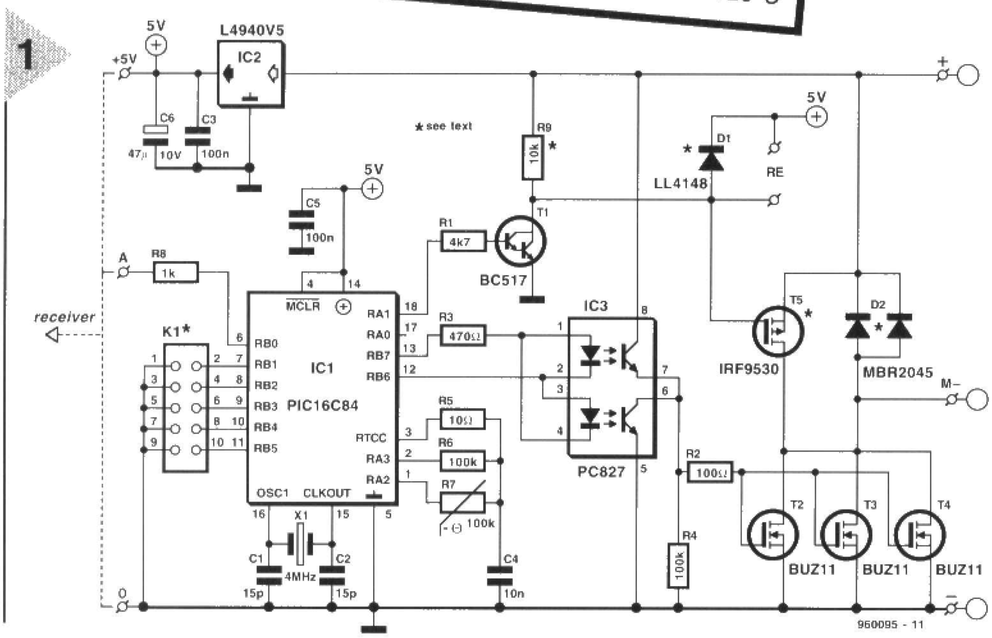

Figure 1. Circuit diagram of the R/C model motor controller. The heart of the circuit is a RISC microprocessor from Microchip Technology Inc.

system, a width of 1 ms corresponds to 'maximum', 1.5 ms, to 'mid-travel', and 2 ms, to 'minimum'. These pulses are sent every 40 ms (i.e., at a rate of 25 Hz). The servo used has an important function because it translates the received pulse width into a corresponding movement of a lever, which changes the setting of the variable resistor via small rod. As a result, the motor voltage increases or decreases, causing the model to accelerate or slow down. The all-electronic version described here replaces the servo, the lever, the rod and the variable resistor in one go. Apart from eliminating the energy waste inherent to a traditional regulator system, the circuit also saves space and weight in the model.

The motor control may be built in two versions. For model planes, the control is used in unidirectional mode (i.e., as an ordinary min./max. regulator). The entire control range is then used to adjust the speed of the propulsion motor over a large range.

The second version operates as a bi-directional control. This type will be used mainly in model boats and cars. The span of the control is then divided into two ranges: 'forward' and 'reverse'. The centre position of the control then corresponds to 'off', i.e., the motor does not run. Because this 'zero' point is rather critical, a certain 'dead' span has been created around it. This is done to prevent the motor reversal relay from 'chattering'. Because this relay is normally fitted in the vehicle, it is not found back in the circuit described here.

A motor braking function has been implemented in unidirectional mode. At the zero setting, this brake short-circuits the motor, allowing the reverse emf (electromotive force) generated by the motor to rapidly reduce the speed of the model to nought.

To make sure that the interface and the used transmitter work happily together, the minimum and maximum propulsion power may be programmed, in addition to the previously mentioned dead zone. In this way, the microprocessor's power is fully exploited.

THE APPROACH

The complete circuit diagram of the motor control is shown in **Figure 1**. The schematic includes all components for unidirectional as well as bidirectional use. The desired version is chosen before building the circuit. Your choice therefore determines the components used. The circuit has been kept as compact as possible. The result: a motor control weighing less than 25 grammes.

The (intelligent) heart of the circuit is formed by a PIC microprocessor (type PIC16C84-04) from Microchip Technology Inc. This miniature RISC processor contains all elements needed for the project. Because control signals always consist of logic levels (pulse width modulated logic signals are found at the input as well as the output), the speed control does not require an A/D converter.

The connection to the receiver is made via a three-wire link, which is standard in model building. In addition to the control signal (A), the interface also receives its supply voltage (+5 volt and ground). In other words, the receiver gets its supply voltage via the motor control.

The control signal supplied by the receiver is applied directly to pin RB0 of the microcontroller (IC1). The other inputs of the microcontroller (RB1-RB5) are connected to pinheader K1, for use during the configuration of the circuit.

Three outputs are significant in the process of controlling the motor speed. The signal used to switch the direction relay (bidirectional version) or the motor brake (unidirectional version) is available at output RA1. Opto-isolator IC3, a type PC827, is driven via outputs RB6 and RB7. The opto-isolator, in turn, drives the transistors that determine the current through the motor. Because high currents are not uncommon in model building, three MOSFETs type BUZ11 are connected in parallel here, the triplet allowing currents of up to 40A to be handled without problems.

As already mentioned, you have to decide on the function of the circuit before you start building it. In the bidirectional version, components T5 and R9 are omitted. In the unidirectional version, D1 and D2 are not required.

The motor is connected between the two terminals marked + and M−. In the unidirectional version, a diode type MBR2045 (D2) is found across these terminals. This dual Schottky diode has been specifically developed for heavy-duty applications, each diode being able to cope with a cur-

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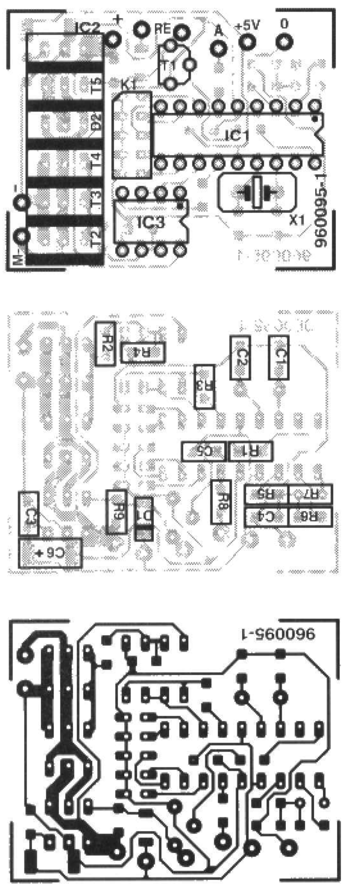

Figure 2. The double-sided board guarantees a compact construction. Components are fitted at both sides! (Board available ready-made through the Readers Services)

COMPONENTS LIST

Resistors:
R1 = 4kΩ, SMD7
R2 = 100Ω, SMD
R3 = 470Ω, SMD
R4,R6 = 100kΩ, SMD
R5 = 10Ω SMD
R7 = NTC, 100kΩ
R8 = 1kΩ, SMD
R9 = 10kΩ, SMD

Capacitors:
C1,C2 = 15pF, SMD
C3,C5 = 10nF, SMD
C4 = 100nF, SMD
C6 = 47µF 10V radial

Semiconductors:
D1 = LL4148*
D2 = MBR2045CT*
T1 = BC517
T2,T3,T4 = BUZ11
T5 = IRF9530
IC1 = PIC16C84 (order code 966510-1)
IC2 = L4960V5
IC3 = PC827

Miscellaneous:
K1 = 10-way pinheader
X1 = 4MHz quartz crystal
Printed circuit board and programmed PIC (IC1): set order code 960095-C (see Readers Services page)
PIC also available separately: order code 966510-1 (see Readers Services page).

rent of 20 A. In this circuit, the MBR2045 acts as a flyback diode to suppress voltage surges generated when the motor is being switched. Diode D1 is the flyback diode which is connected across the relay.

The battery voltage is transformed into a stable voltage of 5 V by an integrated regulator. The 5-V rail is used to power the motor control as well as the receiver.

An NTC (negative temperature coefficient) resistor, R7, allows the motor and battery temperature to be monitored. The value of the NTC resistor is calculated by charging capacitor C4 alternately via R6 and R7.

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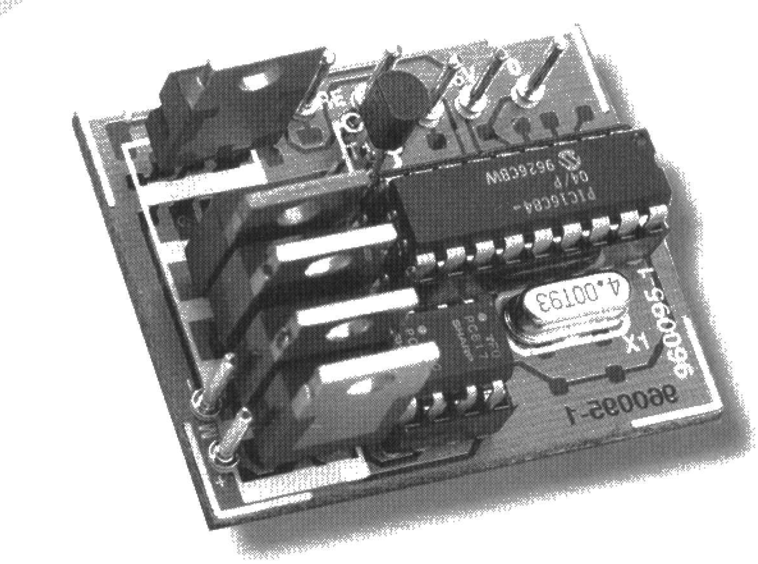


Figure 3. The finished prototype demonstrates the meaning of 'compact'. Thanks to the use of PIC processor, the unit weighs only 23 grammes.

Because the value of R6 is known, the resulting time differences allow the value of R7 to be calculated. At the selected switching thresholds (defined in the software), the protection is actuated at 120°C and switched off again at 80°C. If the protection is not required, the NTC may simply be omitted. The resistance is then, in principle, infinite, which, as far as the controller is concerned, corresponds to a cold motor or battery.

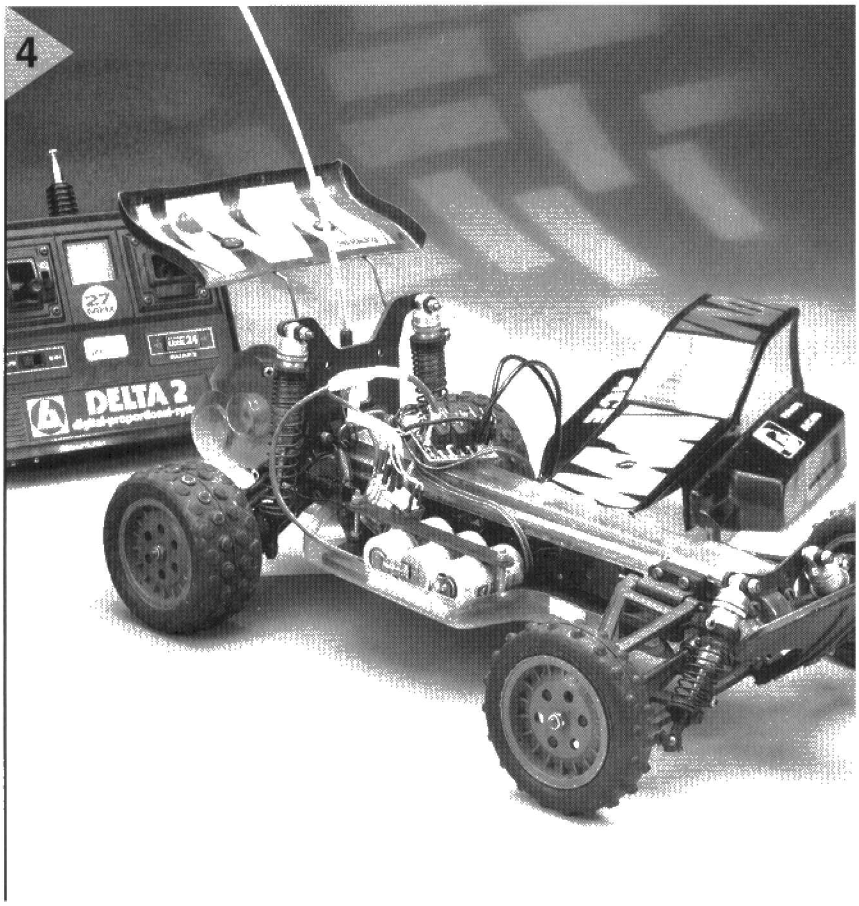
Construction

Now you know the theoretical details of the circuit, you are ready to start building the actual thing. The track layout and component mounting plan of the printed circuit board used to build the control are shown in **Figure 2**. As already mentioned, compactness was a prime issue during the development of the circuit. The PCB is double-sided, and has components at both sides. Where possible, SMDs (surface-mounted devices) have been applied.

Before you start soldering, you have to select between unidirectional and bidirectional mode, because that determines the component content of the circuit. For unidirectional mode, D1 and D2 are omitted, while T5 and R9 are mounted. The opposite applies if the circuit is used in bidirectional mode.

Start by fitting all SMDs at the copper side of the board. This should not be too difficult or time-consuming if you use a fine-tipped soldering iron. Next, you turn the board around, and carefully fit the parts at the top side. If you want, you may fit IC1 and IC3 in sockets. A 10-pin header is used for K1. Heatsinks are not required although pretty large currents may flow in the output stage. None the less, if high currents are a reality, it is recommended to strengthen the copper tracks through which the current flows. In practice, that is easily achieved by soldering a short piece of thick, solid copper wire onto the relevant track section.

The connections for the supply



voltage, the motor, the NTC and the relay are made via solder pins. After inserting the programmed microcontroller into its socket, the circuit is ready for use. Because noise generated by, for example, the motor may upset the operation of the control, it is recommended to fit three 100-nF (0.1-µF) suppressor capacitors across the motor. One capacitor is connected between the two motor terminals, and the other two, between the motor terminals and the motor housing (ground). Finally, we recommend winding the wires that carry the drive signals from the receiver to the control through a ferrite bead (two or three times), as close as possible to the receiver.

Figure 4. The circuit may be used to replace the mechanical speed control in virtually any model, be it a boat, car or plane.

MISCELLANEOUS MATTERS

The mode of the circuit is selected with the aid if jumper JP5. Fitting it selects unidirectional mode, omitting it, bidirectional mode.

In unidirectional mode, set the joystick on the transmitter to minimum speed, and temporarily close jumper JP2 (approx. 1 second). This enables the PIC processor to couple the received pulse time to minimum motor speed. Next, set the joystick to maximum, and briefly close jumper JP1. This links maximum motor speed to the received pulse time. The microcontroller then automatically ensures that the entire speed range is coupled to the span of the control signal.

Roughly the same procedure is followed for the adjustment of the bidirectional mode, only jumper JP2 is then used to determine the maximum reverse speed. Also, the dead zone may be programmed as an extra. Set the joystick to the position which you still want to be interpreted as 'zero', i.e., the highest joystick position that causes zero motor activity later. Briefly close jumper JP3. The controller will record this setting and store it into its memory. All settings are stored in an EEPROM, which allows them to be retained for a long time. A reset during which the default settings are loaded is accomplished by closing jumper JP4 and then switching the supply on. The controller then loads its (internally defined) pre-programmed values (defaults), and all user-programmed values are overwritten.

The speed control may then be fitted into the model and connected to the motor, the receiver and the battery. If you want to make use of the NTC, the component may be fitted on to the motor or the battery. You may then look forward to many happy hours racing your model car, sailing your boat or flying your plane.

(960095-1)

In passing ...

Everybody on the air

Trends and events may take strange turns. Fifteen years ago, you could boost your status immensely by having a mobile telephone installed in your car. The (full duplex) receiver/transmitter would set you back at least a thousand pounds, and a small fortune was required every month to pay the subscription and call costs. Only top managers of large and medium size companies could afford to have a car phone installed. Having the car partly refurbished and a very conspicuous antenna installed on the roof was an excellent way of emphasizing your standing of a successful entrepreneur.

A lot has changed since. The digital revolution has also struck mobile telephony, and yesteryear's status symbol has been replaced by a compact little telephone you get for free if you have your photographs developed, or a few car tyres replaced. Gone is the status symbol; these days, everyone is on the air and always obtainable.

The desire to be obtainable around the clock has become a hype. In Israel, a country where nearly everybody has a mobile telephone in his pocket, and people are seen everywhere holding a phone to the ear, the army has issued a ban on the use of these gizmos. The story is that mobile phones were used during exercises to order pizza's or inform mum that everything's just fine.

Recently, while attending a gathering of many top managers of our company, I, and many others, discovered that one of delegates had forgotten to switch off his mobile phone. It was easy to notice thanks to the beeping sound which came from his jacket just when the welcome speech began. Suddenly crimson in the face, the delegate groped for the on/off switch. Telephone off, I'm unobtainable!

If the mobile telephone was once a status symbol available to the manager to show off his success to competitors and ordinary folk, it is, today, a certificate of incompetence: once you're obtainable around the clock, you're not running your business properly.

Strange days indeed, and all thanks to digital technology. Electronics, what a wonderful profession!

H. Steeman

68HC11 emulator

indispensable tool for active designers

Motorola's 68HC11 is currently one of the world's most popular microcontrollers. This article presents an emulator for this wonderful device. We are pretty sure that the design will appeal to died-in-the-wool as well as budding 68HC11 users, whose patience has been cruelly tried of late by production shortages of some of the most interesting controllers in the Motorola product ranges. On your marks!

Design by J. Gonzales

Main Specifications

Emulation RAM:	*32 Kbytes*
Clock Frequency:	*variable, removable emulator crystal*
Probe boards:	*2, one for stacked-board connection, one for flatcable connection*
Serial interfaces:	*2, one standard (MAX232), 38k4 bits/s max., one electrically isolated (4N35), 19k2 bits/s max.*

Supply connector for all-logic use.
Reset push-button

Special features

Emulator does not employ target system quartz crystal
no debugging under watchdog control
SCI used by emulator
SWI reserved for emulator
XIRQ generally reserved for emulator

The 68HC11 emulator card was designed to fulfill two functions. It may acts as:

• an emulator in single-chip mode for the 68HC11;
• an application board, equivalent to a single chip equipped with 32 kBytes of RAM. In this case, the probe connectors are used to connect to an input/output card. The internal PROM of a 711E9 may additionally load RAM addresses. Priorities are foreseen in the HC11. We have also fitted the emulator with a pair of probes, of which the pinning is identical, but the use, totally different: one for direct connection to the emulator board, and another, which allows the connection to the host circuit to be made via two lengths of flatcable.

In the first case (emulator in 'single-chip' mode), a double approach is available:

Emulator fitted on top of probe board. The total assembly then consists of two boards mounted in 'piggy-back' style (three boards if you include the host board). The emulator card is fitted on top of the probe board, whose pinning corresponds to that of the 68HC11 controller removed from the host system.

Emulator used with probe having flatcable connectors.

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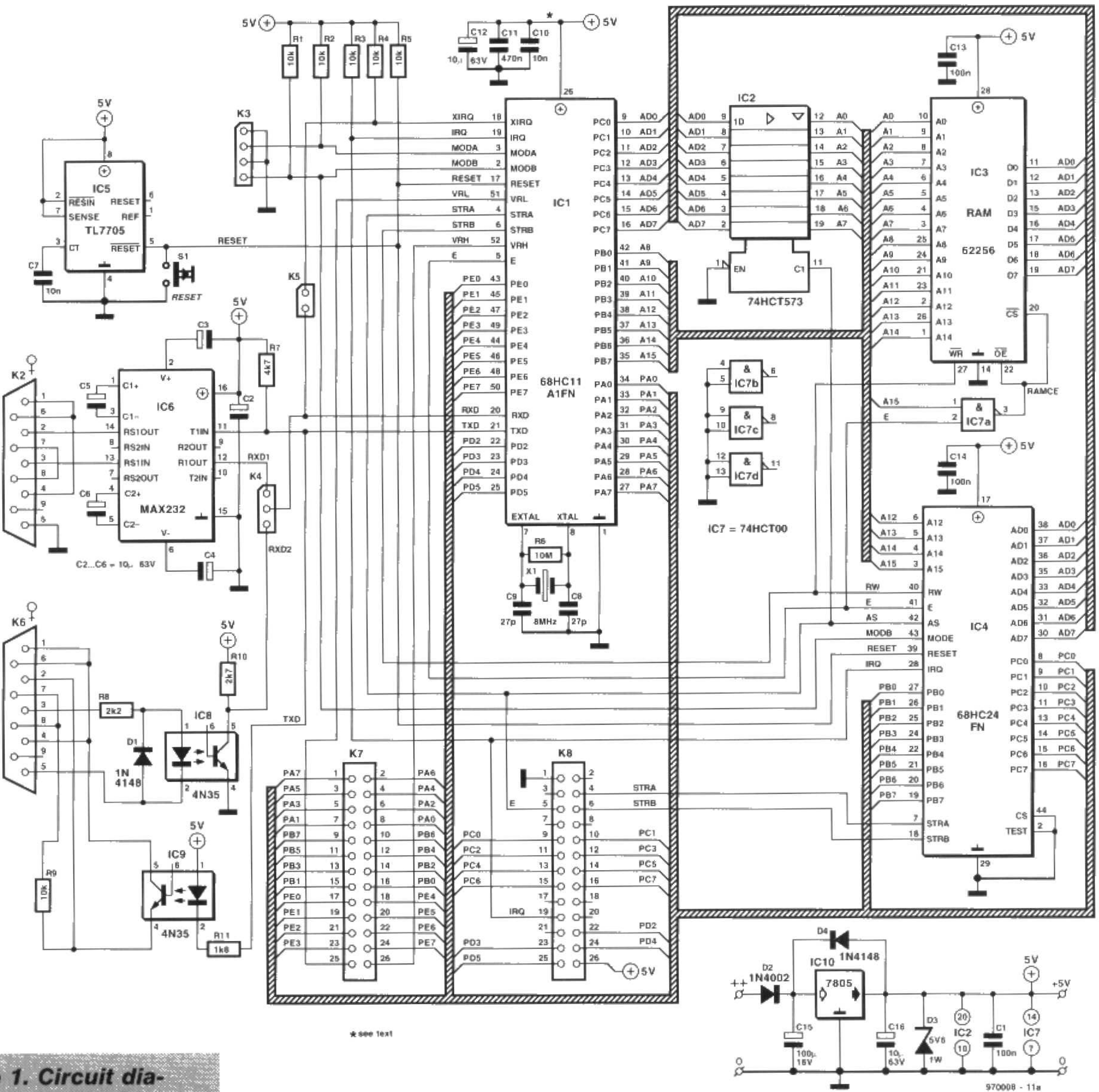

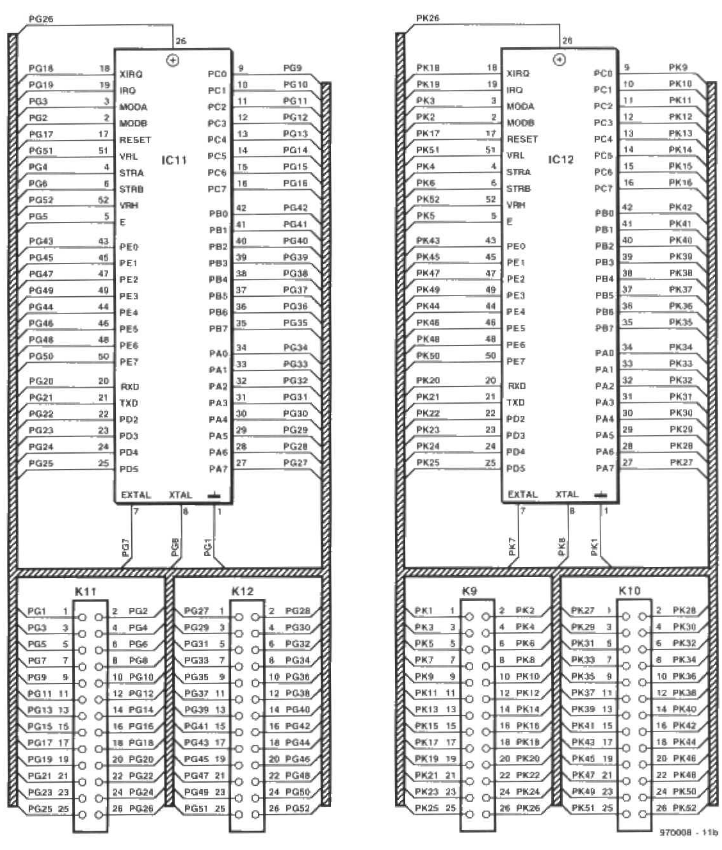

Figure 1. Circuit diagram of the 68HC11 emulator.

Straight, double-row, 26-way connectors connected to the emulator board are then used at the top side, and the probe card is fitted with IDC-style plugs. You have to consider the mounting of the cables carefully if you want to find back the functional equivalent of the card assembly mentioned in the previous paragraph.

THE ELECTRONICS

The schematic shown in Figure 1 may be subdivided into three sub-circuits: in the centre, the components that form the emulator proper, that is, IC1, IC4, IC2, IC3 and their surrounding components. This is actually Motorola's classic scenario for a small emulator consisting of a 68HC11, a 68HC24 and a small memory. The 68HC11 emulator operates in 'TEST' mode (recommended), or 'EXPANDED MUX' mode. In the latter case, ports B and C are lost to form, after multiplexing by 8 bistables in IC2

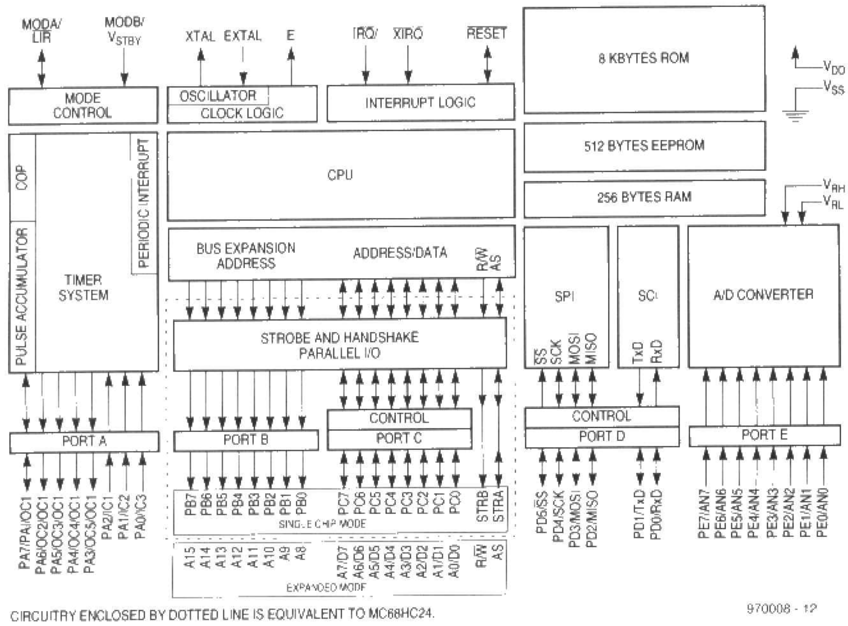

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Figure 2. Architecture of the 68HC11. Note the 68HC24 block. (source: Motorola)

68HC11 Technical Features

M68HC11 central processing unit
512 bytes of EEPROM
No ROM
256 bytes of RAM
16-bit timer system
Real-time interrupt circuit
8-bit 8-channel A/D converter
Serial Communication Interface (SCI)
32 multifunction I/O pins
(divided into 15 bidirectional I/O pins, 12 output pins, and 11 input pins)

(a 74HCT573), the 24 lines of a classic microprocessor bus with 16 address lines and 8 data lines. This microprocessor bus remains confined to the 68HC11 emulator card, only the ports corresponding with the 'single-chip' function are wired to the probe. This bus allows a 32-kByte emulator RAM to be connected. Next, the lost ports (B and C) are recovered by the 68HC24, IC4. The lot thus forms a 68HC11 'single-chip' having 32 kBytes of RAM between $8000 and $FFFF. The emulator will be fitted with an inexpensive HC11, i.e., a 68HC11A1 from any source, or an 68HC11E1, preferably from Toshiba (this has to do with the bootstrap mode). Although it has an external RAM, the card starts in 'bootstrap' mode: 2 jumpers fitted on K3. A pull-up resistor is used on the TxD line because in bootstrap mode port D is initiated using the open-drain option. Next, the Talker utility switches to 'test' mode to have access to the RAM. However, that is of no consequence other than for the RAM amount because the emulator operates in single-chip mode. The function of this emulation RAM (which occupies addresses normally reserved for ROM) is to enable multiple versions of a program to be downloaded very quickly, as well as to allow advanced debugging functions such as *single-stepping*, *JSR stepping*, *no-branch stepping* and *break points* to be used, all in combination with the actual controls and actuators of the host system, and without requiring a power supply. Moreover, electrical isolation is provided between the emulator and the PC.

Those of you burning midnight oil over a simulator for the 68HC11 environment will appreciate all this. The 68HC24 is incompletely decoded: from AD7, we jump directly to AD12, skipping A8 through A11 which are omitted in the decoding. The B and C ports restored by the HC24 are thus redundant. This is really not important for an emulation of a 'single-chip' 68HC11 which contains nothing else at these addresses.

Power supply

The 68HC11 emulator draws its supply current (approx. 20 mA) from the HC11 socket in which the probe is inserted. In the current mode, it is, therefore, not necessary to power it at the level of connector JP1. The TL7705 from Texas Instruments (IC5) is a supply voltage monitor specially designed for use in microprocessor reset circuits. It monitors the supply voltage with the aid of its SENSE input, and detects any (sudden) voltage drop. If the supply voltage drops below 3.6 V, the TL7705 triggers a delay period, at the end of which the RESET and RESET\ outputs are actuated. Here, only the RESET\ line is used (active low).

Peripherals

The serial interface on the emulator board enables the 68HC11 and the PC to communicate, as well as all kinds of programs to be conveyed. The interface is based on the ubiquitous MAX232 (IC6) whose TxD and RxD lines are taken to pins on connector K2. Note that the emulator has to be connected to the PC via a *non-crossed* serial cable. If you do not have such a cable, you may make one yourself from a length of flatcable with IDC-style ('press-on') 9-way sub-D sockets at either end. In some cases, you may have to use a 9-to-25-way adapter because the RS232 port you want to use for the emulator may have a 25-way connector. In many cases, one serial port will be in use for the mouse already.

Brief data on the 68HC11 and 68HC24

The essential components in the emulator are, of course, the 68HC11 and the 68HC24. Unfortunately, a full discussion of all the programming and hardware features of these components is way beyond the scope of this article, and interested readers are referred to Motorola's extensive databooks and application notes. As a useful programmer's aid which is easily consulted during programming sessions, this month's *Elektor Electronics* Datasheets provide an overview of the 68HC11's register array. In addition, the pin-outs of the 68HC11 are presented.

Note that the 68HC11 comes in many different versions. The ones of interest to us are the 68HC11A1 and the 68HC11E1. The architecture of the 68HC11A8 is given in **Figure 2**. It is virtually identical with that of the 68HC11A1. The 68HC11A has two modes of operation: 'single-chip', in which it does not have an address or data bus, and an 'expanded multiplexed' mode in which it is able to access an address range of 64 kBytes. A special bootstrap mode allows programs with a specific function to be loaded into the internal RAM. The 'bootloader' employs the sub-circuit called SCI (*Serial Communication Interface*) for the transfer of a 256-byte program into device-internal RAM, covering the address range $0000 and $00FF. After reception of the character at address $00FF, the program loaded

and launching from address $0000 takes over.

The other essential component is the 68HC24, which is less known than the 68HC11. The '24 is a PRU (*Port Replacement Unit*), a *gate array* designed to emulate the functions of the B and C ports which are 'lost' to the bus extending function in single-chip mode, when the CPU is used in *expanded mode*. This particular mode allows a program in external EPROM to be developed. The internal logic of the 68HC11 has been specifically designed to permit the emulation of single chip functions by a 68HC24.

BUILDING THE BOARDS

The track layouts and component overlays of the double-sided, through-plated printed circuit board designed for the 68HC11 emulator are shown in **Figure 3**. The board is available ready-made through our Readers Services. K7 and K8 on the emulator board are 26-way double-row straight wire-wrap style pinheaders with 0.64-mm square pins at a pitch of 0.1 inch (2.54 mm). The plastic part of the pinheader should be at the component side of the board, and the long (approx. 20 mm) pins are pushed through the PCB holes. The long pins are then carefully soldered from the solder side of the board. They mate with 26-way sockets, K11 and K12, on the larger probe board. The top sides of the square pins mate with 26-way IDC sockets pressed on to flatcables. The other end of each flatcable is secured to a 26-way IDC plug whose pins are soldered to locations K9 and K10 on the smaller probe board. If you can not get hold of double-row 26-way wire-wrap style pinheaders, you may resort to single-in-line strips which may be cut to length and mounted alongside each other.

Each probe board reproduces the 0.05-inch (1.27 mm) pitch PLCC52 footprint of the 68HC11 processor. At the solder side of the probe boards you have to fit 52 0.64-mm square pins with a length of about 8 mm. This is very delicate work, and it is probably best to solder the pins alternately. The aim is to be able, later, to insert these pins into the (empty) PLCC socket for the 68HC11 on the host system board. So, the total assembly of the emulator may consist of three stacked boards (host board, probe board, emulator board). In the author's experience, this type of connection to a PLCC52 socket is sufficiently reliable, although it has not been tested in respect of long-term behaviour.

The alternative is to use the smaller probe board which is connected to the emulator via two flatcables. This solution may be useful if there is limited space above the host system board. The pin connection to the PLCC52 socket remains the same, though, also requiring extreme care in inserting and removing to make sure the pins remain properly aligned with the socket contacts.

THE SOFTWARE

The software developed for the emulator comes on a diskette which may be obtained through our Readers Services, in combination with the PCB, or as a separate item under order code **976002-1**. The disk contains a self-extracting program, M11DISK.EXE, which produces a small (public-domain) assembler, and a programmer/debugger for the 68HC11 called M11.EXE. These two programs should be sufficient to handle almost any situation, with or without the emulator.

Two subdirectories are created which are worth exploring. The first is ASMHC11 which contains Motorola's 68HC11 assembler version 2.0. The second subdirectory is 'M11', which holds the M11.EXE program that arranges the communication with the PC. The program is accompanied by eight other options, each of which giving access to a pull-down menu.

Each subdirectory contains a number of useful 'information' type files in English and French. This program, though running under DOS, is very user friendly. You even have direct access to EDIT.COM, the MS-DOS text editor from Microsoft, without having to quit the M11 program. The Help option gives access to an impressive number of on-line help files.

The other subdirectories are: SAMPLES, HARDWARE and UTILI, which will be reverted to at the end of this article where some examples are presented, and possible problems discussed.

Inside the HC11, M11 launches a small communication utility called Talker. This little program makes use of the serial link to the PC. It also provides access to memory areas and registers which, in turn, enable M11.EXE to create the debugging functions. M11 is easy-going: mouse, pull-down menus, symbols, automatic screen refreshing of memory and register contents. The program will not pose problems to beginners working in 'bootstrap' mode all the time. By contrast, the mode switching of the HC11 and the work that need to be done in between require a deep knowledge of the processor, and lots of programming experience. In all cases, it is essential to have some knowledge of the 68HC11, or at least on Motorola's 8-bit processors in general, and, finally, to examine the examples in the subdirectory SAMPLES. Rummaging through the different .TXT files you may find a lot of useful information.

Even if your have the right development hardware, it is still useful to get acquainted with M11 because being able to switch to special modes and launch them, work without buffers, and being aware that the bus may never left in high-impedance mode (as certain emulators do) may all help you to stay out of, or solve, problematic situations.

The inset lists all Talkers that may be used in conjunction with the emulator. These Talkers switch to 'test' mode to have access to the external 32 Kbyte RAM (mode switching is allowed on the HC11 when you are in a special mode). Note, however, that the vectors are still those of the 'bootstrap' mode, because the bit called 'RBOOT' is not modified by the Talker. This has to do with the fact that the author often uses the same programs, with or without the 68HC11 emulator. Experimentally minded users may want to rewrite and re-assemble these Talkers to obtain the vectors pointing at $BFFF in 'test' mode. *Attention:* if you do that, the vectors used by the Talker for the communication with M11 have to be written to *ad hoc* addresses also, or those which belong to the 'expanded MUX' mode. If you are a 68HC11 specialist, you may want to have a go at creating XIRQ versions of the Talkers type TKA1EEPR or TKAEXPD.S19. Having arrived there, you will discover the many combinations of modes and vector locations, as well as the Talker locations, each of which having its own advantages and disadvantages.

Talkers for use with the emulator

TKAX1TST.BOO	*8-MHz crystal, and PC-HC11 communication at 9,600 baud.*
TKA1XTS.BOO	*5-MHz crystal, and PC-HC11 communication at 19,200 baud*
	10-MHz crystal, and PC-HC11 communication at 38,400 baud.
TKA1XTS-.BOO	*5-MHz crystal, and PC-HC11 communication at 38,400 baud.*

These Talkers use the XIRQ interrupt which has higher priority than the SCI interrupt, so that a jumper has to be fitted on K5. Beginners are advised to stick to these three Talkers.

TKA1TEST.BOO	*Switches to 'test' mode, but does not employ XIRQ*

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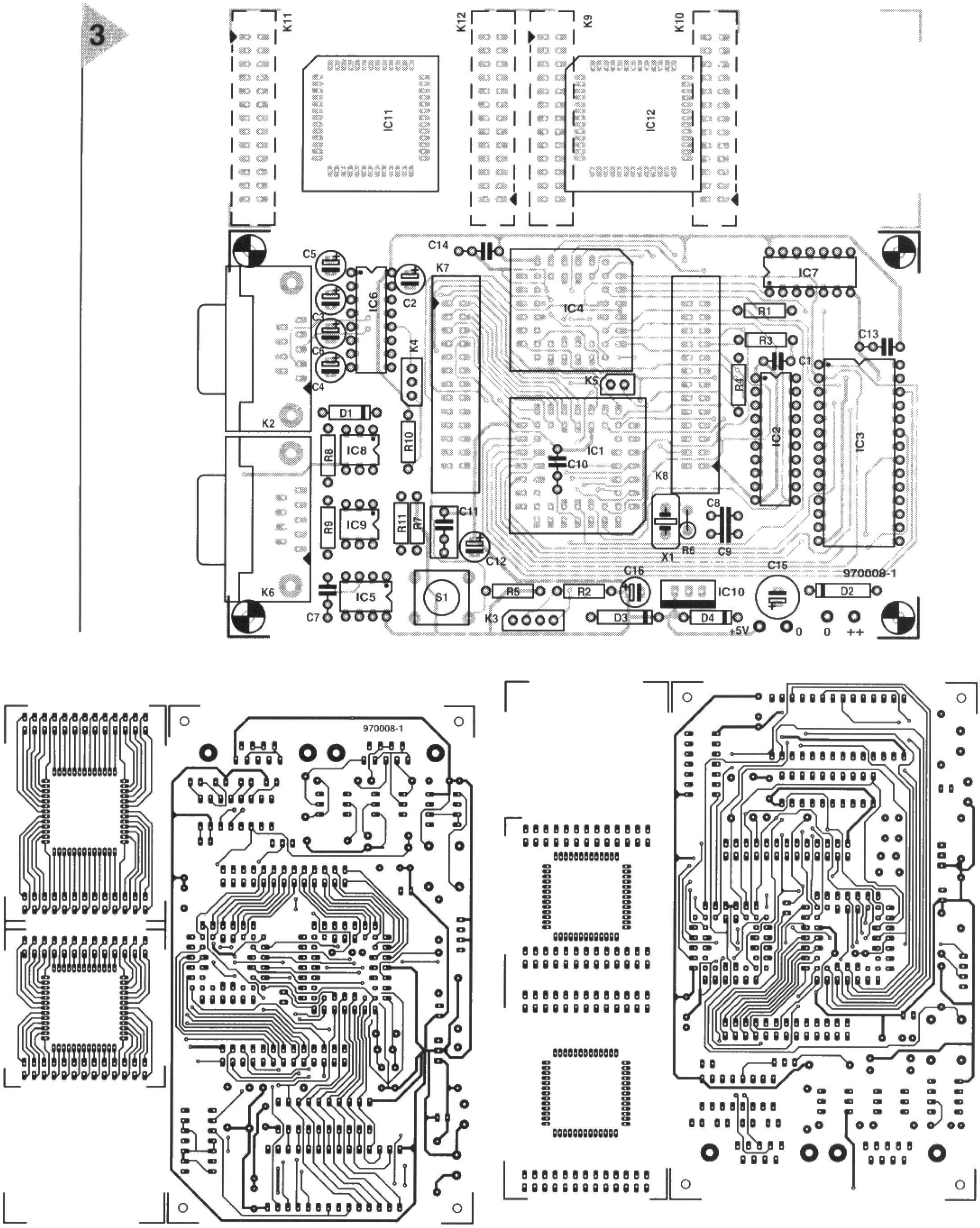


Figure 3. Component mounting plan (actual size) and track layouts (75%) of the PCB designed for the emulator. The double-sided board has to be cut to separate the emulator section from the two probes, which are single-sided boards (board available ready-made, see Readers Services page).

COMPONENTS LIST

Resistors:
R1-R5,R9 = 10kΩ
R6 = 10MΩ
R7 = 4kΩ7
R8 = 2kΩ2
R10 = 2kΩ7
R11 = 1kΩ8

Capacitors:
C1 = 100nF, pitch 5mm
C2- C6,C12,C16 = 10µF 63V
C7,C10 = 10nF
C8,C9 = 27pF ceramic
C11 = 470nF
C13,C14 = 100nF
C15 = 100µF 16V

Semiconductors:
D1,D4 = 1N4148
D2 = 1N4001
D3 = zener diode 5V6/1W
IC1 = 68HC11A1FN (PLCC52 case) (Motorola)
IC2 = 74HCT573
IC3 = 62256
IC4 = 68HC24FN (PLCC44 case) Motorola)
IC5 = TL7705 (Texas Instruments)
IC6 = MAX232 (Maxim)
IC7 = 74HCT00
IC8,IC9 = 4N35
IC10 = 7805
IC11,IC12 = 52 long pins (wire-wrap), 0.64mm square, total length approx. 21 mm

Miscellaneous:
X1 = 8-MHz quartz crystal
S1 = push-button, make contact, e.g. CTL3 (Multimec)
K2,K6 = 9-way sub-D socket, PCB mount
K3 = 4-way SIL pin header
K4 = 3-way SIL pin header
K5 = 2-way pin header
K7,K8 = 26-pin header, wire-wrap, double-row
K9,K10 = 26-way IDC style plug, PCB mount, plus two pieces of 26-way flatcable fitted with 26-way IDC sockets
K11,K12 = 26-way socket, PCB mount
IC sockets: 1 x PLCC52, 1 x PLCC44
PCB and diskette: order code 970008-C (see Readers Services page).
Diskette only: order code 976002-1 (see Readers Services page).

PRACTICAL USE

This article being aimed at experienced microcontroller enthusiasts, and in particular, the fans of the 68HC11, there is probably no need to explain the use and function of an emulator. In practice, one of the probe boards is inserted in the socket from which the 68HC1 processor was removed on the target system board. If there is sufficient space above the host system board, you use the stacked assembly with the larger probe board. If space is tight, it is best to use the smaller probe board attached to the flatcables.

Once the connections are secure (in particular, the 52 pins in the target system socket), it is time to launch the M11 software which enables you to get in touch with the HC11 controller on the emulator board. From there on, it's all software, and there is a lot to discover. The information found on the disk should enable you to make a quick entry into the world of microprocessor emulation. Good luck!

APPLICATION EXAMPLES, FAQS

I have a card of the 'single-chip' type. Now what?
(Very) small applications may be tested and tweaked with the aid of M11.EXE, without the emulator described here, but only if the said card is capable of starting in 'bootstrap' mode. This will be possible with most (simple) cards described in electronics magazines. In all other cases, you will need the emulator hardware, that is to say, if the 'single-chip' application is relatively complex, if you have a card which is unable to start in 'bootstrap' mode, if you want to solve memory size problems more easily, or if you want to use 'C' higher-language programming. A note on the use of 'C': it is possible to create a small debugger source code file with the aid of the Hi-TECH compiler in the M11DISK\UTILI\ subdirectory. In 'C' as well as in 'single-chip' mode, floating-point arithmetic (FPA) is preferably avoided up to the version 711E9, mainly because of the size of the mathematical libraries. The 711E20 is really the first chip suitable for FPA.

I have a card which functions in 'expanded MUX' mode, capable of starting in 'bootstrap' mode. Now what?
Use the M11 software only.

I have a card which functions in 'expanded MUX' mode, but not capable of starting in 'bootstrap' mode. What do I do?
Build the card described in the directory M11DISK\HARDWARE\MINIPROB\. This uses the same type of probe as the 68HC11 emulator, although the connection is established with the aid of flatcable. The mini probe is the equivalent of the emulator for cards of the 'expanded MUX' type. Moreover, it allows '711 processors to be programmed (12 V on the XIRQ pin).

I want to program the PROM/EPROM in the '711 versions.
See above paragraph.

I want to program the EEPROM inside the HC11.
The M11 software is capable of doing this in any case.

I have built an 'expanded MUX' card, but the memory access does not work.
The Talker called TKA1TEST.BOO switches to 'test' mode without moving the vectors, which remain in the internal RAM. The card will therefore function with M11.EXE, although there is no access to external memory. It is then possible to run a small program, in the internal EEPROM, which handles read/write access to/from external memories. This allows the presence of 'chip select' signals, and others, to be verified with the aid of an oscilloscope.

FINAL REMARKS

For circuits that do not consume a lot of power, you may use a floating supply (i.e. without a ground connection). In that case, the PC determines the reference potential if you use the straight (non-isolated) RS232 connection.

The M11 software may be used with any card capable of starting in bootstrap mode. Similarly, the present 68HC11 emulator should, in principle, run with Motorola's PBUG11 software in 'test' mode and using the non-isolated serial link. Note, however, that the Talkers of the two systems should not be mixed because certain software incompatibilities exist at this level.

(970008)

Bibliography

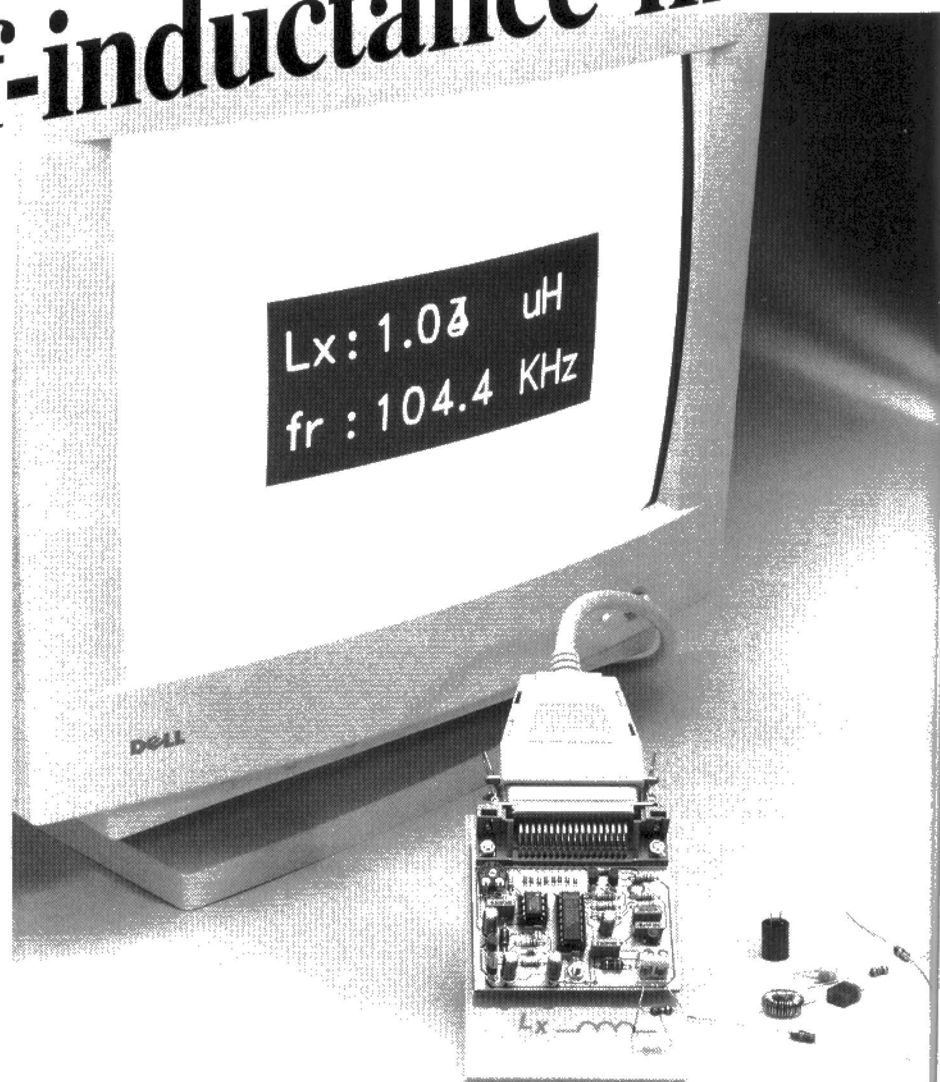
1. *68HC11 Processor Board, Elektor Electronics April 1994*
2. *HC11 MC68HC11A8 Technical Data Book, Motorola.*
3. *AN1060: 'MC68HC11 Bootstrap Mode' Application Note, Motorola, 1990.*
4. *MC68HC11 Programmer's Reference Manual.*
5. *AN456: 'Using PCBug11 as a Diagnostic Aid for Expanded mode M68HC11 Systems', Motorola, 1992.*
6. *AN458: 'A self-test approach for the MC68HC11A/E', Motorola, 1992.*

Internet address:

www.mcu.motsps.com/lit/fam11.htm
this url gives access to the Acrobat Reader file 'HC11RM.PDF' (510 pages, approx. 3 Mbytes, download time approx. 33 min at 28k8)

simple self-inductance meter

for use with a PC



Coils having self-inductance have a mystique for many electronics constructors and designers, particularly amateurs, that is quite unwarranted. Do the mathematics associated with these devices cause this feeling? It is, of course, true that measuring self-inductance is not as straightforward as resistance or capacitance. The most accurate method of measuring self-inductance involves inductive bridges (comparison, Maxwell-Wien, Hay, Owen or Campbell). Where accuracy is not that important, a PC may be used nowadays to measure self-inductance. This article describes a circuit and associated software that enable this to be done in a simple manner.

Design by K. Hagen

Electronics designers and constructors use three main types of passive component: resistors, capacitors, and inductors. The value of the first two is normally easily determined from their colour code or body marking. For most applications, these components are close to the ideal: resistors generally have negligible self-inductance or capacitance, while most capacitors have insignificant resistance and self-inductance. Matters are different with inductors, which usually have some resistance and some capacitance.

Resistance and capacitance can usually be measured directly with a good multimeter but this invariably has no facility for measuring self-inductance. This deficiency can be made good by the interface circuit described which enables a PC to determine the value of an unknown inductance rapidly and (fairly) accurately. The circuit is intended for self-inductances in the range 1 μH to 10 mH, which for most practical purposes is sufficient.

MEASUREMENT METHOD

Coils having self-inductance, that is, inductors, are discrete components with analogue properties. Computers need digital data to operate. So, it is

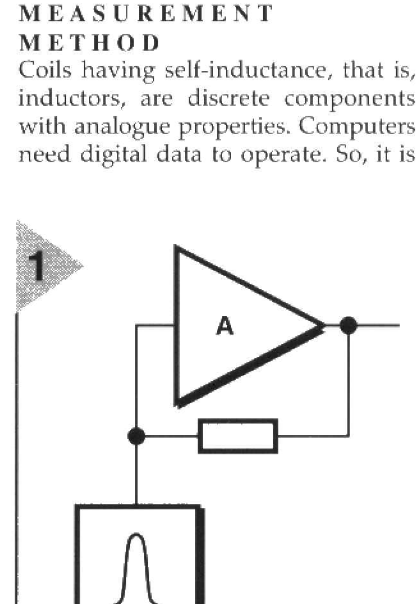


Figure 1. Basic setup of an oscillator using a parallel LC network.

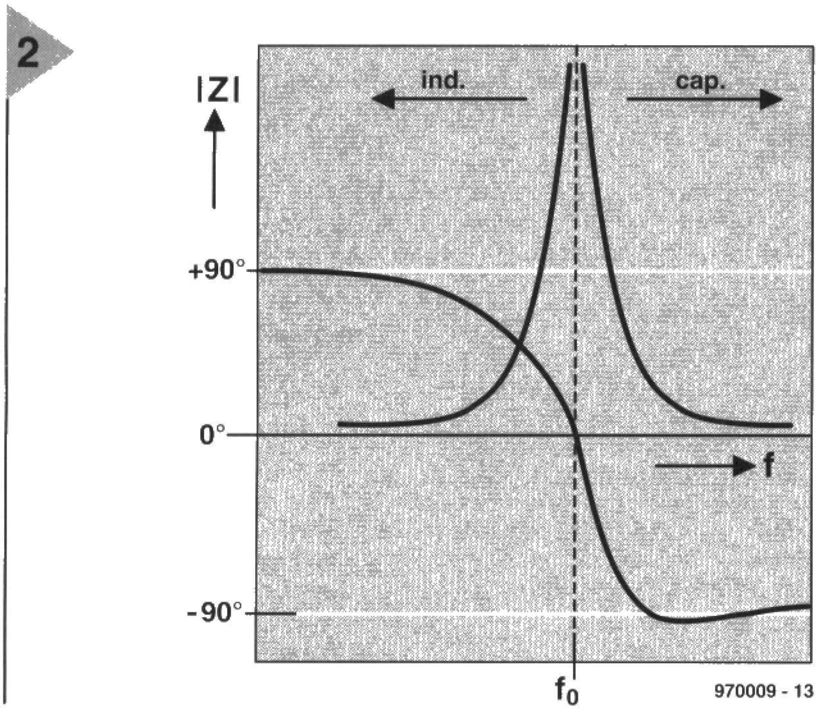


Figure 2. At and near the resonance frequency, the impedance of the LC network is very high and the phase shift is 0°.

necessary for some conversion to be effected and this is the function of the circuit presented here. However, before describing this, a few words on the general method of measurement.

The circuit works on the principle of resonating an *LC* network (oscillator), measuring the frequency and calculating the unknown inductance L_x from the well-known formula

$$L_x = [(2\pi f_r^2)C]^{-1}. \qquad (1)$$

Non-mathematicians need not worry: all this is later done by the computer.

A basic *LC* oscillator is shown in **Figure 1**. Most readers already know that an oscillator is really an amplifier with positive feedback. This feedback is arranged so that it is only available at one single frequency, the resonant frequency. For oscillations to be set up, two conditions need to be met: (1) the amplification at the resonant frequency must be unity, and (2) the phase shift between input and output must be 0. Normally, the (parallel) *LC* network is located between the input and output of the oscillator circuit. **Figure 2** shows the effect a tuned (that is, resonating) *LC* network has on the signal. The impedance at the resonant frequency is very high and the phase shift is 0.

The oscillator output is a sinusoidal signal at the resonant frequency (which is determined by the *LC* network).

CIRCUIT DESCRIPTION

The block diagram of the self-inductance meter is shown in **Figure 3**. This may be divided into two parts: the self-inductance-to-frequency convertor with integral divisor *n*, and the power supply. The circuit proper is shown in **Figure 4**.

The power supply is a step-up regulator, that is, a rectangular waveform generator which magnifies the voltage with the aid of an inductor. Its output is fed to the data outputs of the printer port (LPT) of the PC via diodes D_2–D_9. Although the Centronics definition assumes open-collector outputs with pull-up resistors, TTL buffers are normally used nowadays.

Figure 3. Block diagram of the meter, which consists of a self-inductance-to-frequency converter, a divider network and a power supply.

The data outputs can provide small currents. These are summed via the diodes to give a sufficiently high level to power the entire circuit.

Because the buffers are TTL ports, the output voltage can vary appreciably: levels between 3 V and 4.5 V are not uncommon. This is why the voltage is magnified to convert it into a stable supply of 5 V.

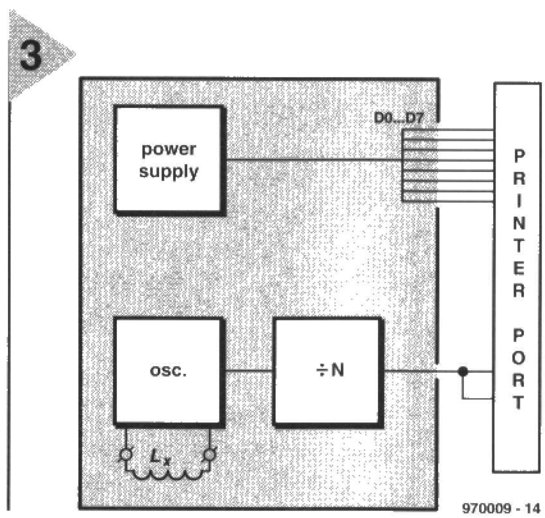
Circuit IC_1 is an astable multivibrator the pulse width of whose output can be varied with preset P_1. The rectangular output signal is used to drive transistor T_1 in a pulsating manner.

The resulting output of T_1 is an alternating voltage across inductor L_1. This voltage is rectified by D_1, resulting in a direct voltage of 10 V.

The direct voltage is converted by IC_2, an integrated 3-pin voltage regulator, into the desired supply potential of 5 V.

In (the unlikely) case the PC cannot supply the circuit, a 1.5 V primary battery may be used as the power source. The battery must be connected between earth and junction B.

The oscillator circuit in the lower part of Figure 3 is based on transistor T_2. The (parallel) *LC* network consists of L_2, the unknown inductance L_x, and capacitors C_7–C_9. Inductor L_2 serves merely to ensure that the network contains some inductance at all times, so that the minimum frequency is always within the measuring range (and this guarantees that the circuit will always start to oscillate). The inductance of L_2 must, of course, be taken into account in the subsequent computations.



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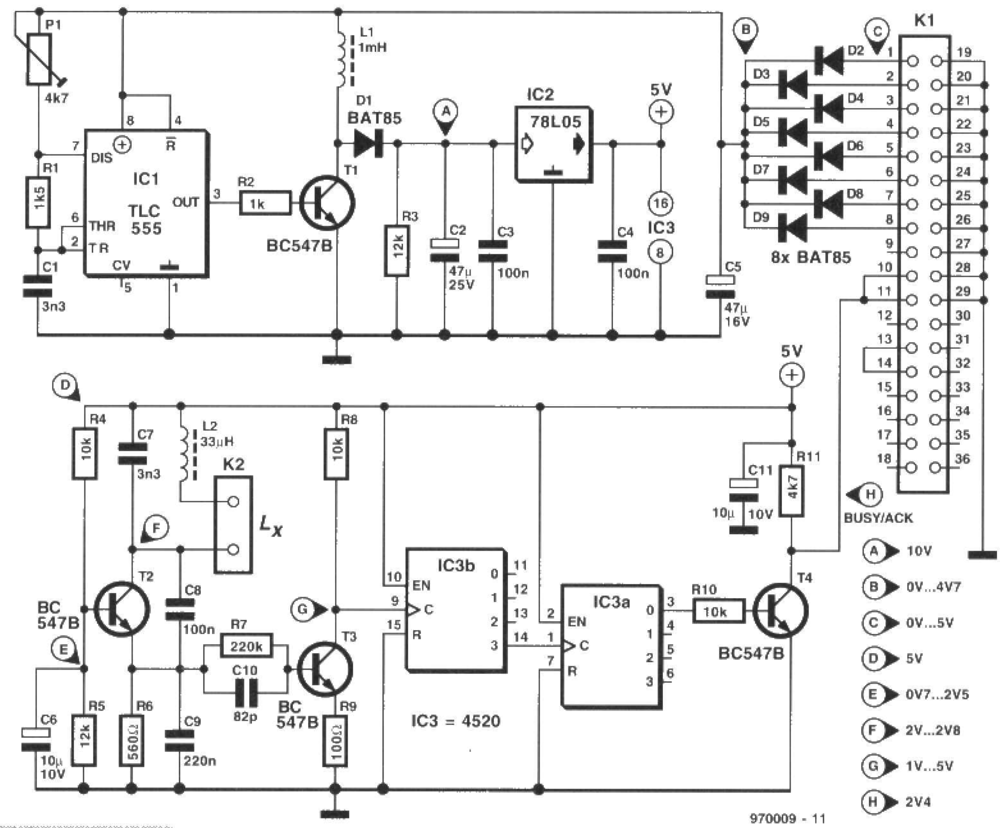

Figure 4. Diagram of the complete circuit. Since all the arithmetic is carried out by a PC, the circuit has been kept fairly compact.

The sinusoidal output of the oscillator is taken from the collector of T_2. Transistor T_3 converts this sine wave into a rectangular signal that can be processed by two series-connected digital dividers. The first of these divides by 2^4 and the other by 2, giving a total division of 2^5 (= 32). Transistor T_4 provides the requisite buffering. Its output signal is taken from the collector and applied to two inputs of the printer port: ack(nowledge) and busy. In practice, one of these inputs is always internally connected.

Figure 5. The printed-circuit board for the self-inductance meter.

CONSTRUCTION

Building the meter is straightforward, particularly if the printed-circuit board in **Figure 5** is used.

Start the work by placing the three wire bridges. Then fit the Centronics connector to the board with two M3 screws, nuts and washers and solder the various terminal pins into place.

Fit connector 2, followed by the resistors, capacitors and diodes. Bend the leads of these components as required with pliers or a bending jig and solder them in place. Mind the polarity of the diodes and electrolytic capacitors.

Finally, fit and solder the transistors and ICs.

When this work is completed, check the board thoroughly for good soldering, polarity where necessary, and correct positioning of all components.

Set preset P_1 to the centre of its travel and connect the board to the printer port of a PC. Switch on the computer and measure the potential across C_2, which should be about 10 V when the associated program has been started (see later). If the potential is too low, readjust P_1 until it is as specified. If it is not possible to obtain this voltage, remove the wire bridge along C_5,

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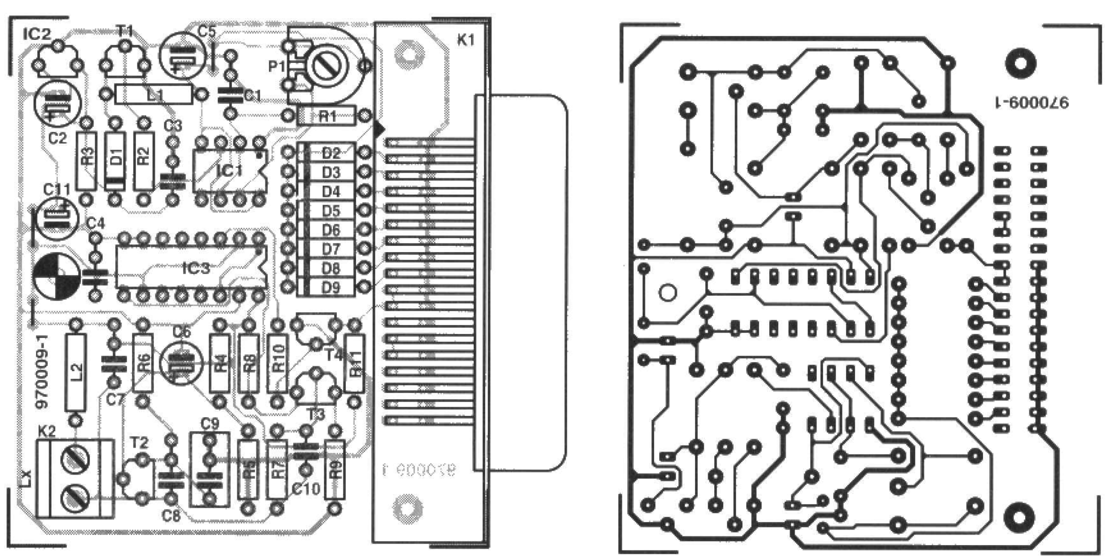

switch off the computer, remove the board from the printer port, and connect a 1.5 V battery across this capacitor. The supply should then be present.

Connect a coil of, say, 1 mH to the terminals marked L_X. Check the voltages at all test points indicated on the circuit diagram. If all is well, the software may be installed.

INSTALLING THE SOFTWARE

The software is available via the Readers Services (see towards the end of this issue) against Order No. 976001. It contains a DOS as well as a Windows version. In either case, the installation is straightforward.

In case of the DOS version, copy the directory with the DOS program to the hard disc, and start program COILCE.EXE. That's all!

In case of the Windows version, start the associated installation program, INSTALL.EXE. The program copies the requisite files and prepares an icon.

CALIBRATION

For the calibration, it is assumed that the value of the capacitors is known. Capacitor C_7 is shunted by series-connected C_8 and C_9; the replacement value of this combination is 72.05 nF. The text in the box shows how this value can be calculated. If the value of the individual capacitors can be measured, the calculated value is very precise. In case of doubt, use the stated value.

In configuration file COILCE.CFG, both the value of the replacement capacitance and that of the self-inductance are stated. Short-circuit the terminals marked L_X and have the software determine the measured value, which must be 0, but will probably not be. Alter the value of the self-inductance in the configuration file until the measured value is 0.

SOMETHING WRONG?

In spite of careful work and a thorough inspection, it may happen that the meter does not function correctly. As a first step in the faultfinding

Parts list

Resistors:
R_1 = 1.5 kΩ
R_2 = 1 kΩ
R_3, R_5 = 12 kΩ
R_4, R_8, R_{10} = 10 kΩ
R_6 = 560 Ω
R_7 = 220 kΩ
R_9 = 100 Ω
R_{11} = 4.7 kΩ
P_1 = 4.7 kΩ preset

Capacitors:
C_1, C_7 = 3.3 nF, polyester
C_2 = 47 µF, 25 V, radial
C_3, C_4 = 100 nF, high stability
C_5 = 47 µF, 16 V, radial
C_6, C_{11} = 10 µF, 10 V, radial
C_8 = 100 nF, polyester
C_9 = 220 nF, polyester
C_{10} = 82 pF, ceramic

Inductors:
L_1 = 1 mH
L_2 = 33 µH

Semiconductors:
D_1–D_9 = BAT85
T_1–T_4 = BC547B

Integrated circuits:
IC_1 = TLC555
IC_2 = 78L05
IC_3 = 4520

Miscellaneous:
K_1 = 36-way Centronics socket, right-angled
K_2 = 2-way terminal block, pitch 5 mm
PCB+software package
Order no. 970009-C
If the PCB is not required, the software may be ordered against
Order no. 976001

Some arithmetic

Broadly speaking, the analogue value of the self-inductance is converted into the digital value of the frequency by the oscillator.

The resonant frequency, f_r of a parallel LC network is

$$f_r = 1/2\pi\sqrt{LC}$$

from which

$$L = [(2\pi f_r^2)C]^{-1}.$$

Since C has a known value, 2π is a constant, and the frequency can be measured, the value of the inductance may be calculated very easily.

In the calculation it is assumed that ideal components are used, because a measurement error of 2–5 per cent is perfectly acceptable

Equivalent capacitance

The equivalent value, C_{e1}, of two series-connected capacitors is

$$C_{e1} = C_8C_9/(C_8+C_9).$$

The equivalent value, C_{e2}, of two parallel-connected capacitors is

$$C_{e2} = C_8C_9/(C_8+C_9) + C_7,$$

so that the equivalent value, C_{e3}, of the three capacitors in Figure 4 is

$$C_{e3} = 10^{-7} \times 22 \times 10^{-8} / (10^{-7} + 22 \times 10^{-8}) + 3.3 \times 10^{-9}$$

$$= 72.05 \times 10^{-9} = 72.05 \text{ nF.}$$

This value is used in the configuration file that forms part of the program. The value of inductor L_2, also stated in this file, must be deducted by the computer from the calculated value to arrive at the value of L_X.

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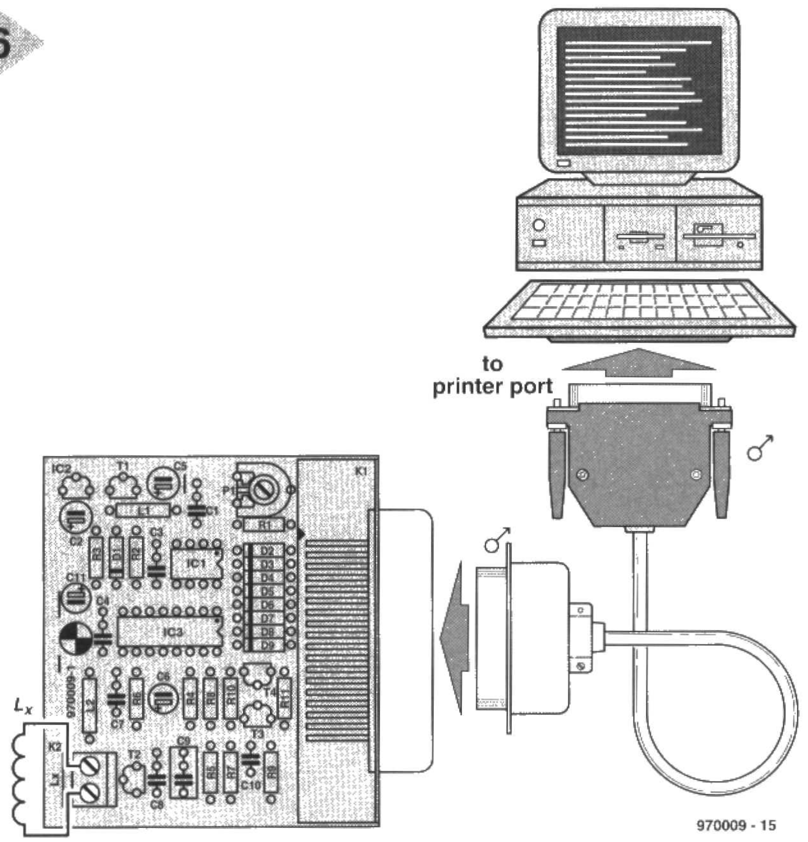

Figure 6. Connecting the meter to the PC is straightforward via a printer cable to the Centronics port. The unknown inductance is connected to the terminals marked L_x.

process, check whether the software can be started; if so, the meter is correctly linked to the computer.

The operation of the meter itself is checked with the aid of a number of test points indicated in **Figure 4** and a multimeter.

Check that the voltage at test point A w.r.t. earth is 10 V. If the measured value is low, check the potential at test point B. If this is 3 V or more, the regulator is not functioning properly. If there is an alternating voltage at pin 3 of IC_1, the oscillator works. Check T_1, the polarity of D_1, and the self-inductance of L_1.There must be a fault here somewhere.

If the voltage at test point B is lower than 3 V and diodes D_2–D_9 are mounted correctly, the power from the PC is not suitable. In that case, use a discrete battery.

If the voltage at test point D is 5 V and the meter does not function properly, check the operation of the oscillator thoroughly. Check the potential at test point E. If this is quite different from that specified and resistors of correct value have been used, T_2 is defect or the wrong type.

Check the voltage at test point F. If this differs from the specified value, there is an open-circuit in L_2 or L_x.

Check the potential at test point G, which should be about 2.5 V. If so, the oscillator works correctly and the fault must be in the dividers.

Check the voltage at pins 3 and 14 of IC_3, which must be about 2.5 V. If so, transistor T_4 is faulty or of the wrong type. [970009]

Figure 7. Photograph of the completed prototype, which converts a PC to a self-inductance meter.

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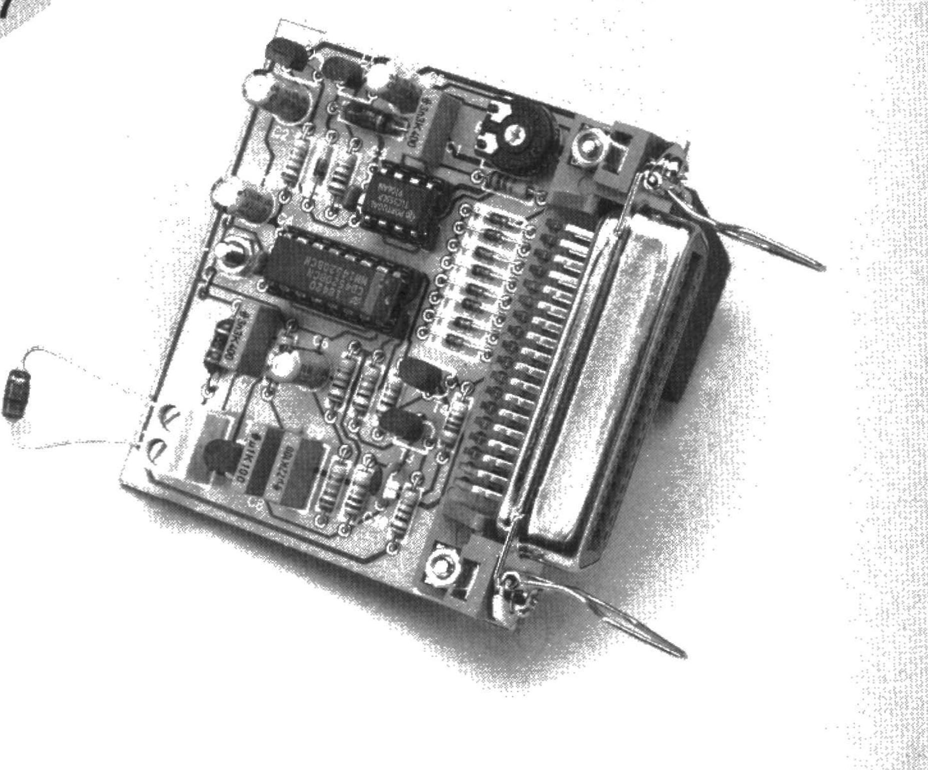
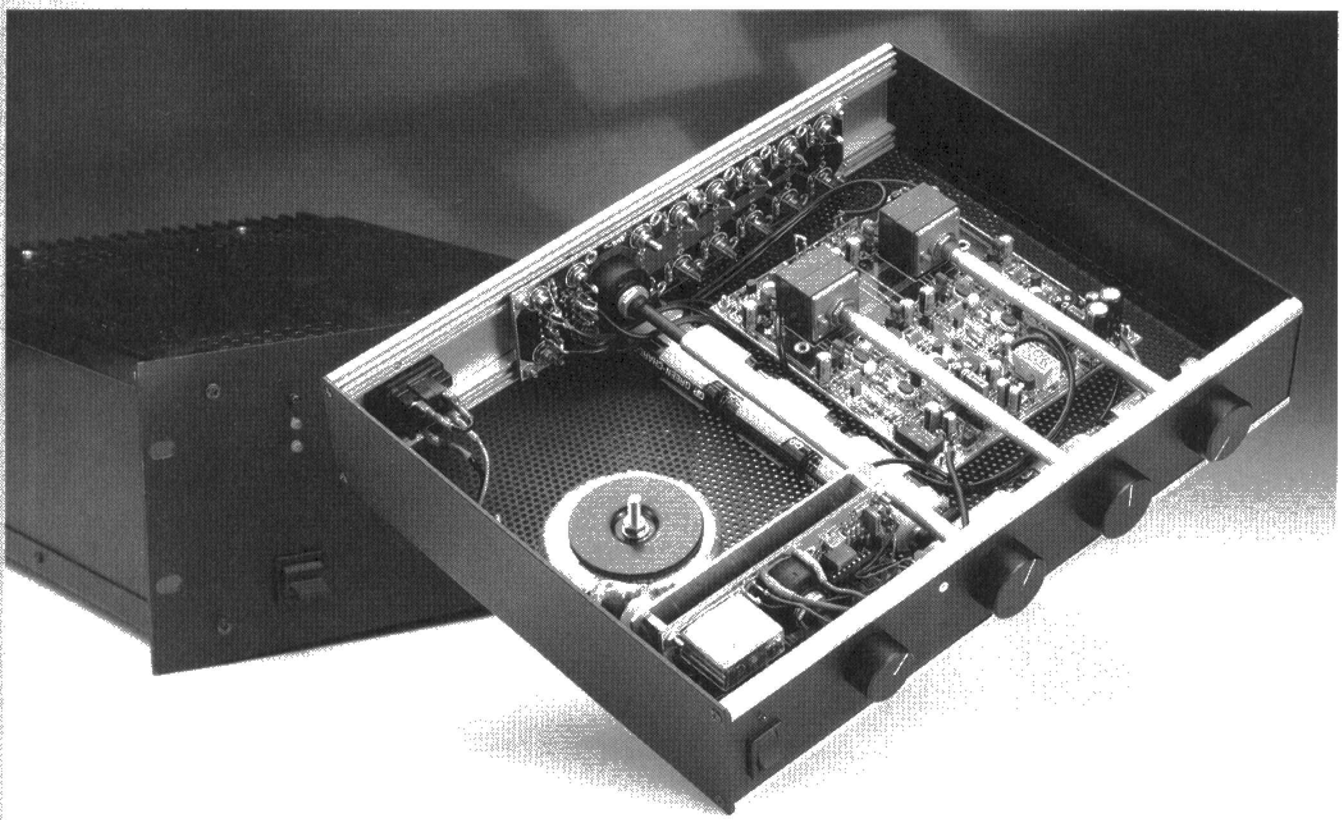


battery-operated AF pre-amplifier - part 2



power supply and construction

Following the detailed description of the preamplifier in last month's instalment, this second and final part of the article deals with the power supply and the construction of the complete unit. More so than usual, the power supply forms an important part of the overall design. It consists of 12 NiMH batteries, size AA (RG/HP7) with a nominal capacity of 1.2 Ah, and a moderately fast charger that takes about three hours to fully charge a set of flat batteries (note that it is not a good idea to discharge these batteries completely – the nominal voltage level is maintained at 1.2 V during 80% of the discharge cycle).

Design by T. Giesberts

Since the current drain of the preamplifier is not more than 21 mA, a set of fully charged 12 NiMH batteries will enable the preamplifier to operate about 50 hours continuously. As this type of operation is seldom, if ever, required, there is normally plenty of time for the batteries to be recharged. Note, by the way, that NiMH batteries are free of the undesirable memory effect. Nevertheless, NiCd batteries may be used if for one reason or another NiMH batteries cannot be obtained. Unlike NiMH batteries, NiCd cells will show some degradation of capacity in the long term.

The charger is based on the well-known Type TEA1101 IC, which is eminently suitable for this purpose since it uses the ΔU method for controlling the charging current. With this method, the terminal voltage of the battery rises gradually when it is being charged. When the battery is fully charged, its temperature rises, which causes a

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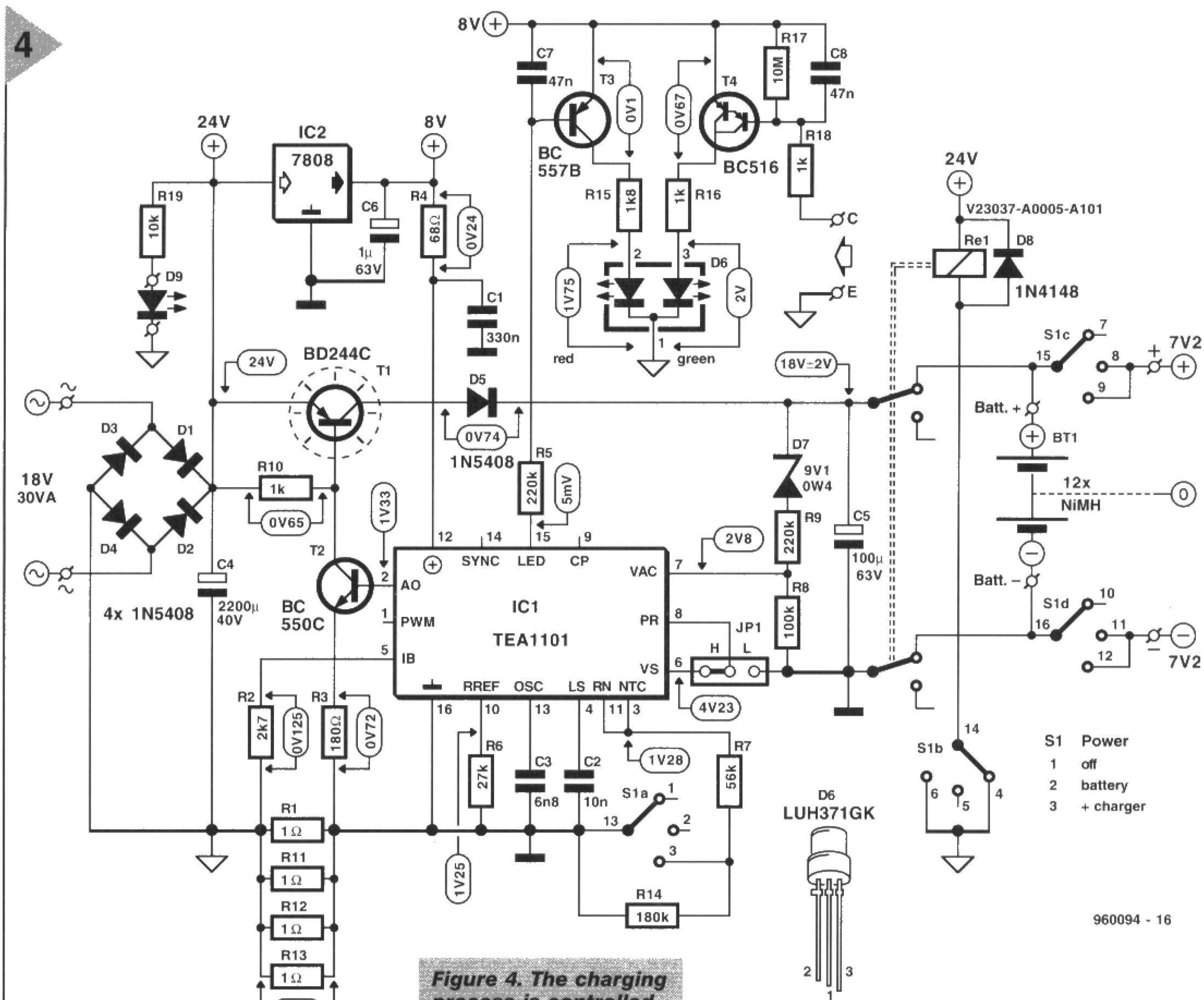

Figure 4. The charging process is controlled by a Type TA1101 IC. Flat batteries are fully charged in about 3 hours. After this period, trickle-charging begins.

slight drop in terminal voltage (ΔU). The TEA1101 monitors this process continuously and regularly cuts off the charging current whereupon a precise measurement of the terminal voltage takes place. When the circuit registers the drop in terminal voltage, the full charging current is switched off and replaced by a trickle-charging current.

The level of the full charging current is 500 mA, which is high enough to charge the batteries in a fairly short time, but not so high as to require temperature monitoring of the cells. The trickle-charging current is 5 mA, but this can be altered slightly if desired.

CIRCUIT DESCRIPTION

In the circuit diagram in **Figure 4**, switch S_1 is a quadruple three-position switch. In position 1 (off), the link between the batteries and the preamplifier is broken by S_{1C} and S_{1D} – the preamplifier is then off. At the same time, double-pole relay Re_1 is energized via S_{1B}. The relay contacts connect the charger to the batteries, whereupon the batteries are being charged. Note that this happens only when the charger is linked to the mains supply, since otherwise the relay cannot be energized.

In position 2 (battery), the preamplifier is connected to the batteries via S_{1C} and S_{1D}, so that it is switched on. At the same time, the relay is deactuated via S_{1B}, so that the charger is disconnected from the batteries.

In position 3 (+ charger), which should not often be used, the preamplifier is switched on and the batteries are being charged. This position is really only for those situations where the batteries are flat and the preamplifier is to be used.

The various modes of operation are indicated by a number of LEDs. One of these, D_9, is the on/off indicator for the charger. The red half of D_6, a dual diode, is controlled by the LED output of IC_1 and lights up continuously during normal charging and flashes during trickle-charging.

If terminals C and E are linked to the corresponding terminals on the preamplifier, lighting of the green half of D_6 shows that the preamplifier is switched on.

Both halves of D_6 may light to give a mixture of colours. A continuous orange colour shows that the preamplifier is on and that the batteries are being charged. Green combined with flashing orange indicates that the preamplifier is on and that the batteries are being trickle-charged.

Some people may find it odd that the batteries are drawn as one unit, whereas in reality they are arranged in two sets of six, each of which provides one half of the symmetrical supply voltage. They are charged in series. The common line is taken from the junction between the 6th and 7th battery.

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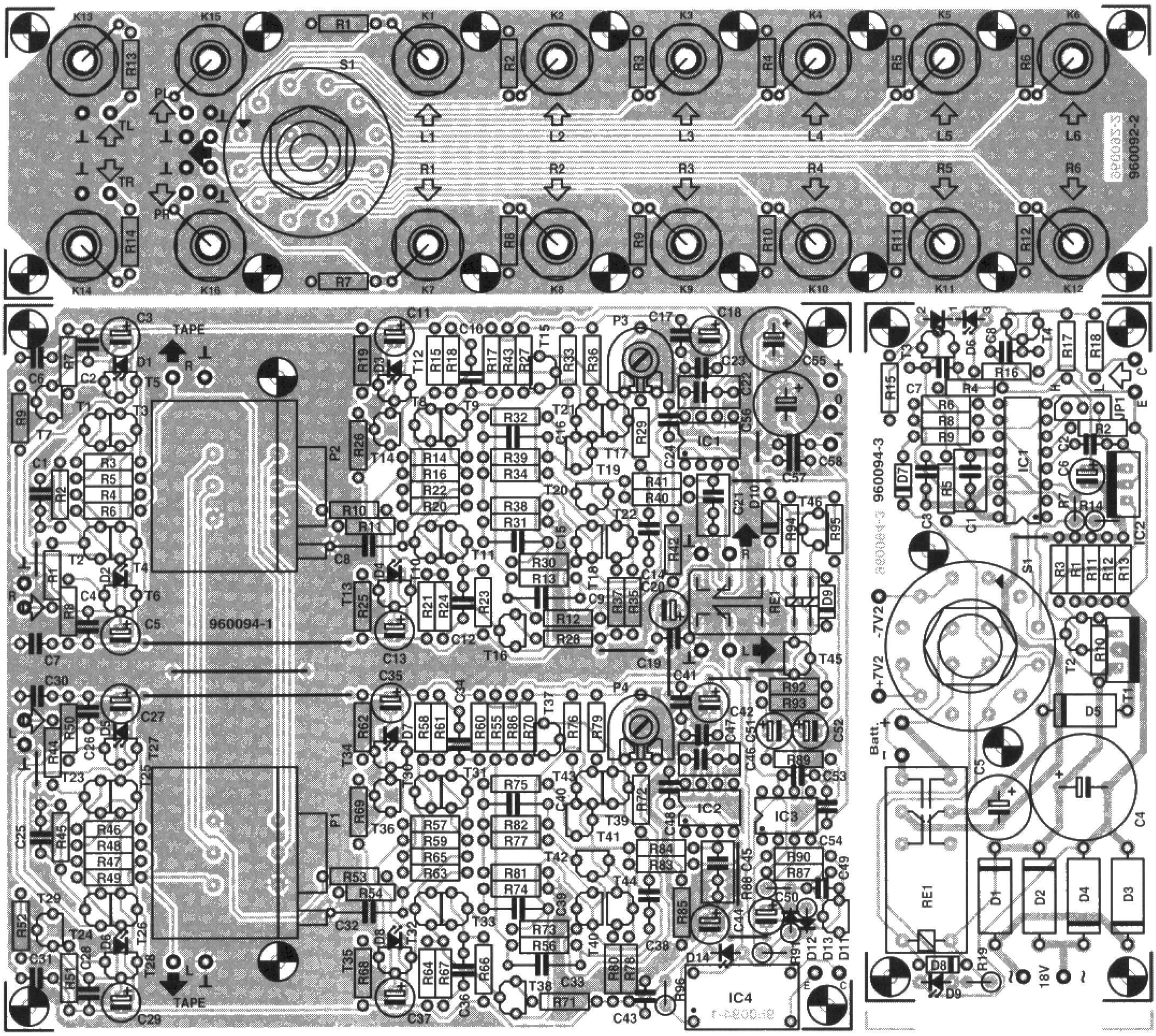


Parts list PREAMPLIFIER

Resistors:
R_1, R_{44} = 560 Ω
R_2, R_{11}, R_{45}, R_{54} = 47 kΩ
R_3, R_4, R_{46}, R_{47} = 150 Ω
R_5, R_6, R_{48}, R_{49} = 47 Ω
R_7, R_8, R_{19}, R_{25}, R_{50}, R_{51}, R_{62}, R_{68} = 1 kΩ
R_9, R_{15}, R_{17}, R_{21}, R_{23}, R_{26}, R_{52}, R_{58}, R_{60}, R_{64}, R_{66}, R_{69} = 2.2 kΩ
R_{10}, R_{53} = 1.2 kΩ
R_{12}, R_{55} = 3.3 kΩ
R_{13}, R_{31}, R_{56}, R_{74}, R_{88} = 10 kΩ
R_{14}, R_{16}, R_{20}, R_{22}, R_{40}, R_{57}, R_{59}, R_{63} R_{65}, R_{83} = 1– Ω
R_{18}, R_{24}, R_{61}, R_{67} = 220 Ω
R_{27}, R_{28}, R_{70}, R_{71} = 470 Ω
R_{29}, R_{30}, R_{72}, R_{73} = 1.8 kΩ
R_{32}, R_{34}, R_{75}, R_{77} = 1.5 kΩ
R_{33}, R_{35}, R_{39}, R_{76}, R_{78}, R_{82}, R_{92}, R_{94} = 4.7 kΩ
R_{36}, R_{37}, R_{79}, R_{80} = 68 Ω
R_{38}, R_{81} = 6.8 kΩ
R_{41}, R_{42}, R_{84}, R_{85} = 470 kΩ
R_{43}, R_{86} = 680 kΩ
R_{87} = 820 kΩ
R_{89} = 10 MΩ
R_{90} = 270 kΩ
R_{91} = 2.2 MΩ
R_{93}, R_{95} = 39 kΩ
R_{96} = 1 MΩ
P_1 = 10 kΩ stereo linear, special balance (Alps)
P_2 = 10 kΩ stereo log (Alps)
P_3, P_4 = 25 kΩ preset

Capacitors:
C_1, C_{25} = 1 nF
C_2, C_4, C_6, C_7, C_{14}, C_{17}, C_{19}, C_{23}, C_{24}, C_{26}, C_{28}, C_{30}, C_{31}, C_{38}, C_{41}, C_{43}, C_{47}, C_{48}, C_{49}, C_{53}, C_{54}, C_{57}, C_{58} = 100 nF ceramic
C_3, C_5, C_{11}, C_{13}, C_{18}, C_{20}, C_{27}, C_{29}, C_{35}, C_{37}, C_{42}, C_{44} = 100 μF, 25 V, radial
C_8, C_{32} = 150 pF, 160 V, polyester
C_9, C_{33} = 47 pF, 160 V, polyester
C_{10}, C_{12}, C_{34}, C_{36} = 1.2 nF
C_{15}, C_{16}, C_{39}, C_{40} = 22 pF, 160 V, polyester
C_{21}, C_{22}, C_{45}, C_{46} = 330 nF
C_{50} = 47 μF, 25 V, radial
C_{51}, C_{52} = 1 μF, 63 V, radial
C_{55}, C_{56} = 470 μF, 25 V, radial;

Semiconductors:
D_1–D_8 = LED, red, rectangular, 5 mm
D_9, D_{10} = 1N4148
D_{11} = LT1004CZ-1.2 (Linear Technology)
D_{12}, D_{13} = BAT85
D_{14} = low-current, green, 5 mm
T_1, T_4, T_5, T_{10}, T_{11}, T_{12}, T_{15}, T_{18}, T_{20}, T_{21}, T_{23}, T_{26}, T_{27}, T_{32}, T_{33}, T_{34}, T_{37}, T_{40}, T_{42}, T_{43} = BC560C
T_2, T_3, T_6, T_8, T_9, T_{13}, T_{16}, T_{17}, T_{19}, T_{22}, T_{24}, T_{25}, T_{28}, T_{30}, T_{31}, T_{35}, T_{38}, T_{39}, T_{41}, T_{44} = BC550C
T_7, T_{14}, T_{29}, T_{36} = BF245A
T_{45} = BC557B
T_{46} = BC547B

Integrated circuits:
IC_1–IC_3 = OP90GP (Analog Devices)
IC_4 = CNY65 (Temic/Telefunken)

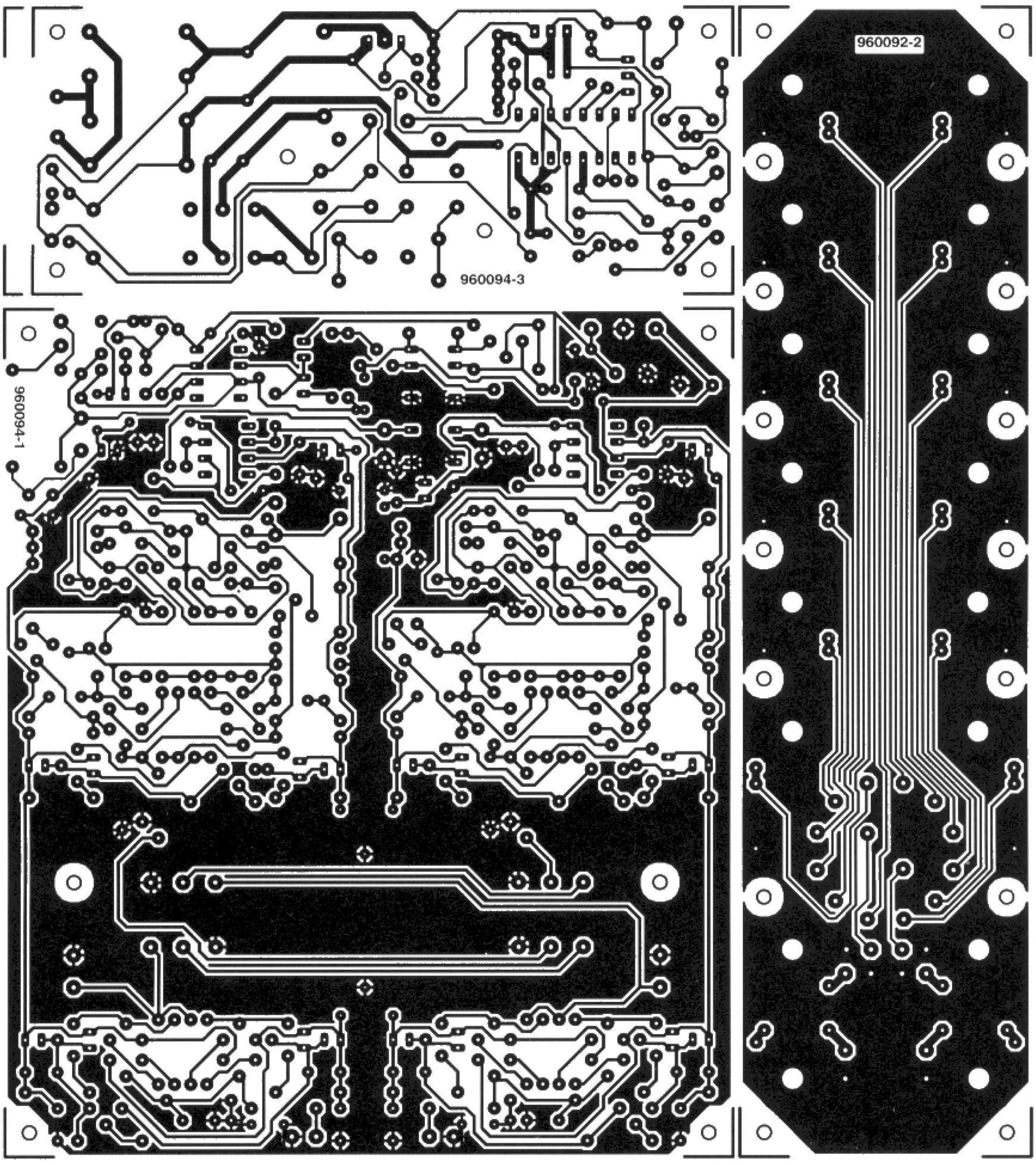
Miscellaneous:
Re_1 = bistable relay, 2 change-over contacts
Case 300×57×235 mm (12×2¼×9¼ in), e.g. Monacor UC-202H/SW

Figure 5. The printed-circuit board for the input selector, preamplifier and charger must be cut into three as indicated before any further work is done.

Parts list INPUT SELECTOR

Resistors:
R_1–R_{12} = 47 kΩ
R_{13}, R_{14} = 470 Ω

Miscellaneous:
K_1–K_{16} = audio socket (preferably gold-plated) for chassis mounting
S_1 = rotary switch, 2-pole, 6-position, for board mounting



Parts list CHARGER

Resistors :
R_1, R_{11}, R_{12}, R_{13} = 1 Ω
R_2 = 2.7 kΩ
R_3 = 180 Ω
R_4 = 68 Ω
R_5, R_9 = 220 kΩ
R_6 = 27 kΩ
R_7 = 56 kΩ
R_8 = 100 kΩ
R_{10}, R_{16}, R_{18} = 1 kΩ
R_{14} = 180 kΩ
R_{15} = 1.8 kΩ
R_{17} = 10 MΩ
R_{19} = 10 kΩ

Capacitors:
C_1 = 330 nF
C_2 = 10 nF
C_3 = 6.8 nF
C_4 = 2200 μF, 40 V, radial
C_5 = 100 μF, 63 V, radial
C_6 = 1 μF, 63 V, radial
C_7, C_8 = 47 nF

Semiconductors:
D_1–D_5 = 1N5408
D_6 = dual LED, 4 mm, common cathode
D_7 = zener diode 9.1 V, 400 mW
D_8 = 1N4148
D_9 = LED, low current, 3 mm
T_1 = BD244C
T_2 = BC550C
T_3 = BC557B
T_4 = BC516

Integrated circuits:
IC_1 = TEA1101 (Philips)
IC_2 = 7808

Miscellaneous:
JP_1 = 3-way header and jump lead
S_1 = rotary switch, 4-pole, 3-position, for board mounting
Re_1 = relay, 24 V, 1100 Ω coil, 2 change-over contacts
Mains transformer 18 V, 30 VA secondary, preferably toroidal
Mains fuse = 160 mA, slow-acting
Single-pole mains on /off switch

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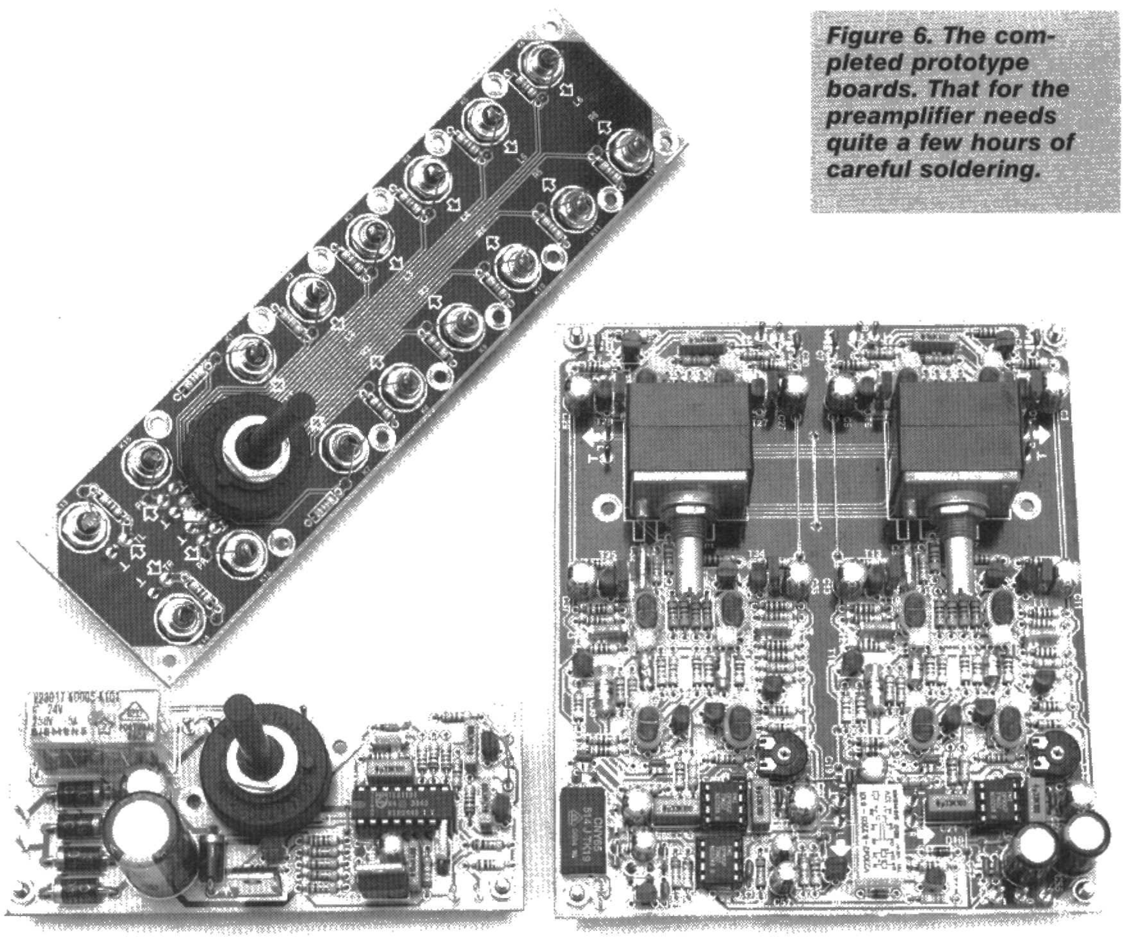

Figure 6. The completed prototype boards. That for the preamplifier needs quite a few hours of careful soldering.

BATTERY MONITOR

The remainder of the circuit in Figure 4 is a linear regulator arranged in the standard application of the TEA1101 suggested by the manufacturers.

Voltage regulator IC_2 provides the 8 V supply for IC_1.

The secondary voltage of the mains transformer is rectified by D_1–D_4 and smoothed by C_4. The value of this electrolytic capacitor is purposely taken higher than strictly required to enable the circuit to be used with higher charging currents.

The control loop is formed by transistor T_1, the batteries, current sensor R_1-R_{11}-R_{12}-R_{13}, and driver T_2. The latter transistor is controlled via pin 2 (A0) of IC_1. Diode D_5 prevents the batteries being discharged via T_1.

The prime function of IC_1 is performed by a monitor and control network whose input is pin 7 (VAC). The input to this pin is part of the battery voltage taken from potential divider D_7-R_8-R_9. The internal monitor regularly checks the potential at pin 7. During these periodic tests, the charging current is discontinued via pin 2. Each measured voltage is quantized and compared with the previous one. If the new value is higher, it is stored; if it is lower, a check is made whether the difference (ΔU) is greater than 0.25% (owing to the presence of D_7, this comes down to 0.125%). If the latter is the case, normal charging is replaced by trickle-charging.

When at the onset of the charging cycle the value at pin 7 is below the reference value of 380 mV, IC_1 arranges for the cycle to start with trickle-charging. Only when the potential at pin 7 rises above the reference value does normal charging begin. If no difference is measured, IC_1 acts as if the battery is defect and disconnects the charging current.

When at the start of the charging cycle the potential at pin 7 is high, IC_1 acts as if no battery is connected and resets the circuit.

The value of the charging current is determined by resistor R_6 (connected to pin 10): with the resistor value as specified, it is 500 mA.

The level of the trickle-charging current is determined normally by R_7-R_{14}: with values of these components as specified, the current is 5 mA. With S_1 in position 3, charging takes place with the preamplifier on and the trickle-charging current must then be increased to compensate for the current drain of the preamplifier. This is achieved by S_{1A} short-circuiting R_{14}, whereupon the trickle-charging current rises to about 25 mA.

The duty factor of the trickle-charging pulses may be lowered with jumper JP_1. This may be handy in case good-quality batteries are used which have no measurable self-discharge. Normally, JP_1 should be in position H; when it is set to position L, the duty factor is lowered by 75%, which means an effective drop of the trickle-charging current to 1.25 mA.

It should be borne in mind that for both the quality of the preamplifier and the correct functioning of the charger it is vital that the transfer resistance in the battery holders is kept as low as possible. The total transfer resistance should not exceed 4.5 Ω. So, it is advisable to use high-quality holders, preferably with sintered terminals.

CONSTRUCTION

The entire unit, that is, the input selector, preamplifier proper and charger, is best built on the printed-circuit board shown in **Figure 5**. This consists of three sections which, before any further work is done, should be cut apart.

Completing the input selector board is simplicity itself, since it contains only the input and output sockets, the selector switch and terminal resistors.

The preamplifier board is densely populated and needs to be completed with great care. Accurate soldering is of prime importance, since a number of terminals and copper tracks are very close together.

It is of vital importance that transistor sets T_1-T_3, T_2-T_4, T_8-T_9, T_{10}-T_{11}, T_{17}-T_{21}, and T_{18}-T_{22} are in good thermal contact. Therefore, their cases

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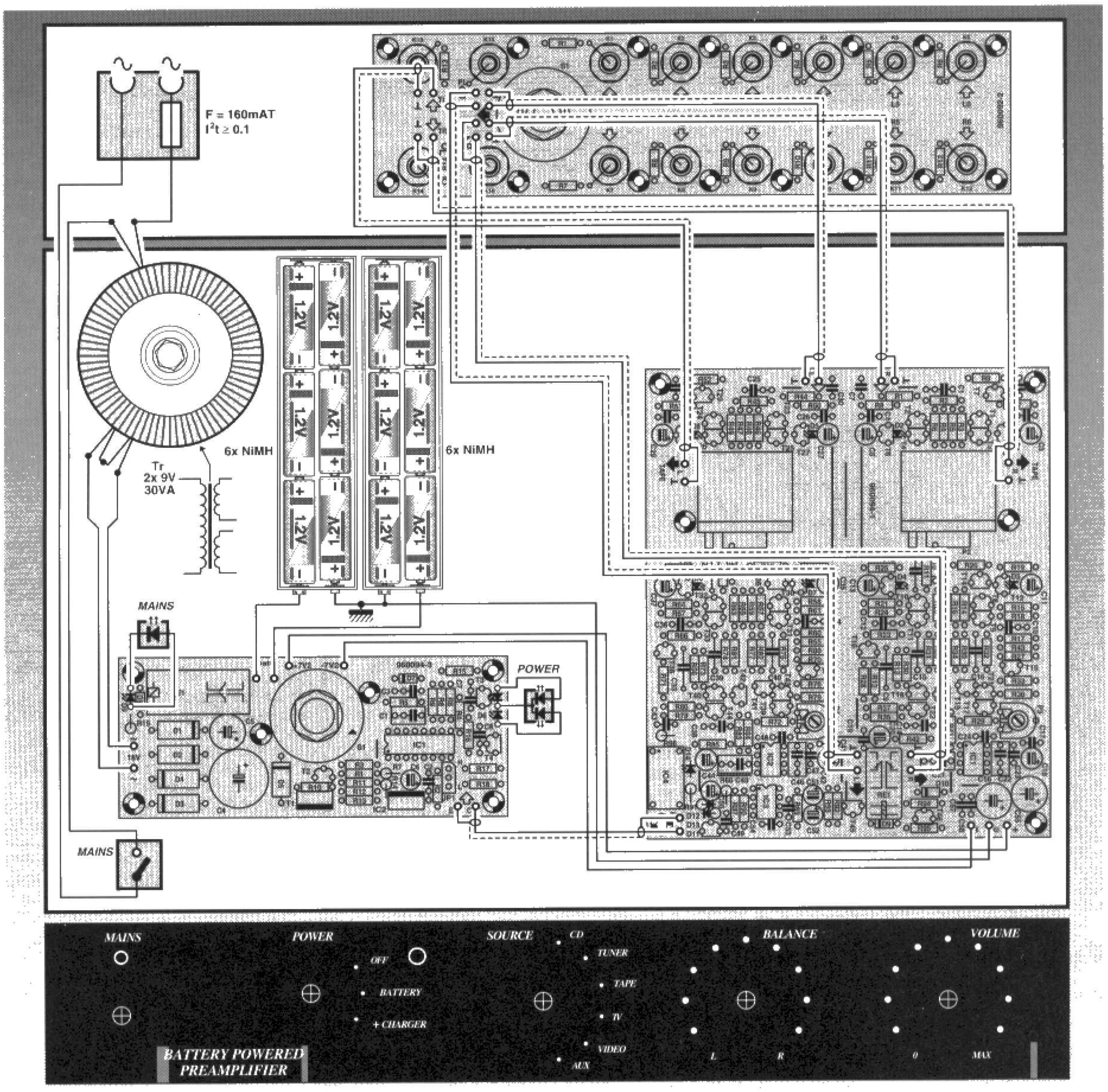

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Figure 7. The wiring diagram shows that the link between the preamplifier common and case earth is connected to the junction of the 6th and 7th battery.

should be linked firmly with the aid of, for instance, a nylon cable strap pulled as tight as possible. Good thermal coupling is also necessary between D_1–D_8 and the associated transistors. So, use rectangular diodes and fit them tightly against the flat side of the adjacent transistor: cable straps are not necessary here.

There is ample room on the board for the balance control and volume control. This has the advantage that the distances between the various components are as short as feasible and that no cables are needed between the controls and the board. The spindles of the controls are fitted with special extensions to the front panels (as in the case of the input selector).

Both the balance control and the volume control are closed Alps types. In the case of the balance control, this is a special model with half-silvered tracks to prevent attenuation when the control is at the centre of its travel.

Finally, it is imperative that axial lead 160 V polystyrene capacitors be used in the C_8, C_9, C_{15}, and C_{16} (C_{32}, C_{33}, C_{39}, and C_{40}) positions. Do not use ceramic types, which are not suitable and do not fit on the board.

Completion of the charger board is, like that of the input selector board, a piece of cake. Again, the rotary switch is mounted directly on the board. Bear in mind that D_6 and D_9 have to be visible at the front panel.

Cooling of transistor T_1 is best effected by fitting the device isolated on a small sheet of aluminium to the bottom the enclosure.

Do not forget the jumper!

The completed prototype boards are shown in **Figure 6**.

CHECKING & TESTING

When the boards have been completed, it is good practice to carry out a thorough check of the work. Are all diodes and electrolytic capacitors fitted with correct polarity? Are all ICs fitted correctly? This kind of check may save a lot of time later on if there is a malfunction.

When the boards appear to be all right, connect the mains transformer in a provisional, but safe way to the ~ terminals on the charger board. Do not yet connect the batteries. Measure the potential across C_4, which should be about 24 V, and across C_5, which should be 1–2 V lower. Check that the output voltage of IC_2 is about 18 V and, if so, connect the batteries. The operation of D_6 shows whether the charger works correctly. If so, charge the batteries fully. In the unlikely case that the charger does not function correctly, check that the potentials at the test points shown in Figure 4 are as shown.

Next, link the batteries to the supply terminals on the preamplifier board. The subsequent faint lighting of diodes D_1–D_8 indicates that by and large the preamplifier works correctly. The quiescent current is set to 2 mA by

Table 1 Test voltages *(preamplifier - Figure 1)*

measured across:	*Potential*
D_1–D_8	1V6
R_7–R_9, R_{19}, R_{25}, R_{26}, R_{50}, R_{51}, R_{52}, R_{62}, R_{68}, R_{69}	1 V
R_3, R_4, R_{46}, R_{47}	0V15
R_5, R_6, R_{48}, R_{49}	0V13
R_{14}, R_{16}, R_{20}, R_{22}, R_{57}, R_{59}, R_{63}, R_{65}	0V05
R_{15}, R_{17}, R_{21}, R_{23}, R_{58}, R_{60}, R_{64}, R_{66}	1V1
R_{27}, R_{28}, R_{70}, R_{71}	0V5
C_{14}, C_{38}	1V7
R_{32}, R_{34}, R_{75}, R_{77}	0V25
R_{33}, R_{35}, R_{76}, R_{78}	0V78
R_{36}, R_{37}, R_{79}, R_{80}	0V14 (set with P_3, P_4)
pins 4 and 6 of IC_3	0V4
D_{11}	1V23
R_{90}	1V72
D_9, D_{10}, R_{92}, R_{94}	0 V
measured between earth and:	***Potential***
base T_1; junction R_5-R_6; base T_8; junction R_{38}-R_{39}; junction R_{39}-R_{40}; pins 2 and 3 of IC_1	0 V
base T_{23}; junction R_{48}-R_{49}; base T_{30}; junction R_{81}-R_{82}; junction R_{82}-R_{83}; pins 2 and 3 of IC_2	0 V
pin 6 of IC_1; pin 6 of IC_2	0 V (if not, select devices)

connecting a multimeter (1 V d.c. range) across R_{36} or R_{37} (R_{79} or R_{80}) and adjusting P_3 (P_4) to obtain a meter reading of 140 mV.

For clarity's sake, the voltages at the various test points in Figure 1 have been omitted and are shown in **Table 1**. Note that all potentials were measured with a digital multimeter (high input impedance). If the measured voltage deviate no more than 10% from the specified ones, it may be assumed that all is well.

Be careful when using an oscilloscope for testing the preamplifier not to link the common lines of the charger board and the preamplifier board as this would short-circuit the negative supply line.

ASSEMBLY & WIRING

Any type of metal enclosure may be used as long as the boards fit into it easily. It is best to mount the charger board directly behind the front panel, the input selector board to the rear panel and the preamplifier board in between. The spindles of the various controls and switches must, of course, be provides with suitable extensions.

Mind that D_6 and D_9 can be seen at the front panel.

Fit a mains switch on the front panel and the mains entry with integral fuse at the rear. The fuse should be a slow type rated at 160 mA (I^2t>>0.1). Use well-insulated wire for the connections between mains entry, transformer and on/off switch.

With the boards positioned as indicated, the (toroidal) mains transformer and battery holders fit nicely in the space behind the charger board. Keep the transformer away as far as possible from the input selector board and as close as feasible to the mains entry.

Although the wiring has been kept to a minimum, a wiring diagram is shown in **Figure 7**. The links between the input selector board and the preamplifier board need to be single screened audio cable. This type of cable is also used for interlinking terminals C and E on the charger board and the preamplifier board.

The supply lines may be normal flexible stranded circuit wire. Note that the common of the preamplifier board functions as the earth: as the wiring diagram shows, it is connected directly to the junction of the 6th and 7th battery. This junction should also be strapped to the earthing point of the metal case. Do not connect the earth of the charger board to the case earth since that would short-circuit the supply line. It is for this reason also that T_1 must be isolated from the case.

Figure 8 (scale 8:10) shows a suggested front panel layout and marking for the case: this is not available ready made.

[960094-2]

ELEKTOR	
240V~ 50Hz	
No. 960094	
F = 160mA T	

8

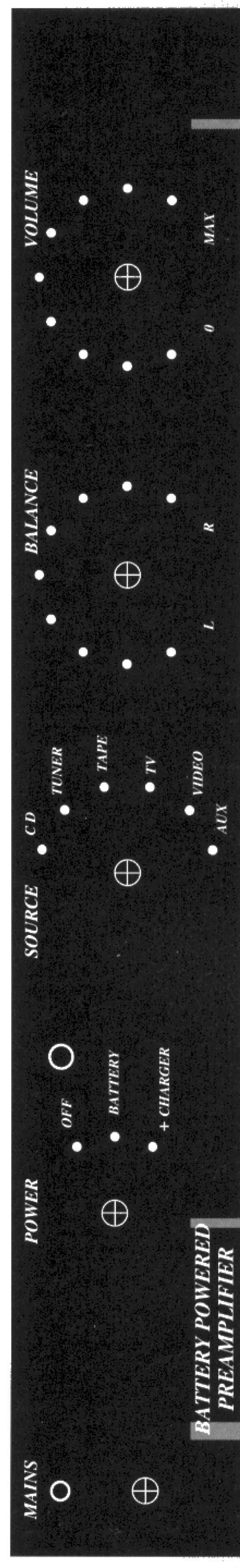


Figure 8. Suggested front panel layout and marking for use with the Monacor case.

electronics on-line

question time

With a contribution by Jason McDonald (USA)

Technicians and scientists around the globe usually face trouble when it comes to finding the right background information for their specialization. As a matter of course, communication is essential in finding solutions, and here, again, the Digital Highway offers plenty of opportunities to add to one's own knowledge lots of information other people already put in writing. Internet documents containing Frequently Asked Question (FAQ) lists may often provide the answer to a burning question. The only problem that remains to be solved then is locating the right FAQs on the net. This article aims at providing a few tips which may help to make the process of locating information a little easier.

FAQ is a phenomenon which pops up literally anywhere on the Internet. As indicated by the acronym, FAQ files contain lists of frequently or at least regularly asked questions that pop up in a newsgroup, thousands of which are currently active via the net. These FAQs are consulted by millions of net users every day. The discussions within the newsgroups may be about scientific research, computer use, or background information for a highly specific subject (such as PC hardware). As might be expected, a lot of questions have been answered already by other Internet users. Almost any newsgroup has its FAQs and, of course, the answers to them, stored in a file. The newsgroup moderator collects frequently asked questions and stores them in file which may be downloaded by anyone subscribing to the newsgroup. FAQ files remain on the newsgroup servers for a long time, so that the information is also available to the occasional visitor. By contrast, the original correspondence that created the subject matter of the FAQs is often only available for a short time, and may have been removed months ago by the time you log in. FAQ lists allow Internet users to get at the crux of the subject without too much leafing through large sites. For electronics enthusiasts, too, the net has many interesting FAQ files in stock.

Where are you?

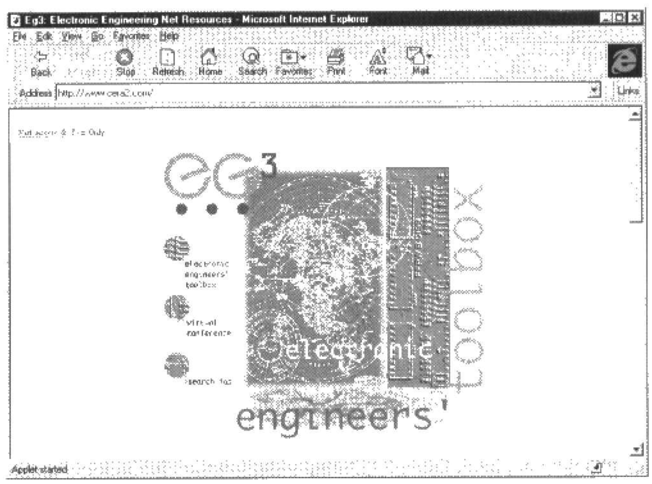
Once you are aware of the fact that the Internet may provide the answers to certain questions, the remaining problem is where to find the FAQ lists. Our advice is to always employ the familiar search engines in your quest for certain FAQs. These engines are specifically designed for this job, and always contain the latest information. Suppose you are stuck with a question about the Motorola 680000 processor. Very likely, the answer may be found in the FAQs about this processor. The quest is very short indeed: Go to the Infoseek search engine at **http://guide.infoseek.com** and select the *Web FAQ* option. Type the search key, in this case, 'Motorola' or '68000'. As an aside, the search key 'electronics' may help you to find the answer to a general question in electronics. After a few seconds, the screen is filled with locators of documents which may contain the answer to your question.

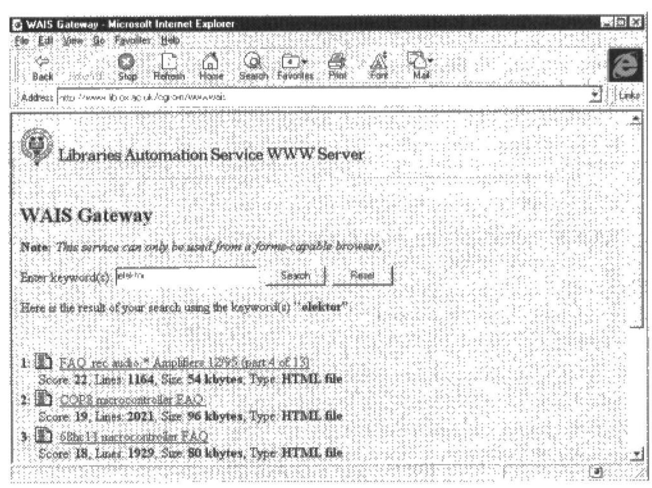
The search commands may be specified in more detail by typing the 'closer' indication 'sci/electronics' instead of just 'electronics'. This restricts the search to information in newsgroups discussing scientific aspects of electronics (although that should be taken with a pinch of salt, *Tech. Ed.*)

An alternative search engine which is eminently suited to our purposes is the one operated by Oxford university at **http://www.lib.ox.ac.uk.search/search - faqs.html.**

Cera Research, too, chips in by publishing a master list of electronics-related FAQs at **http://www.cera2.com.**

(975013)

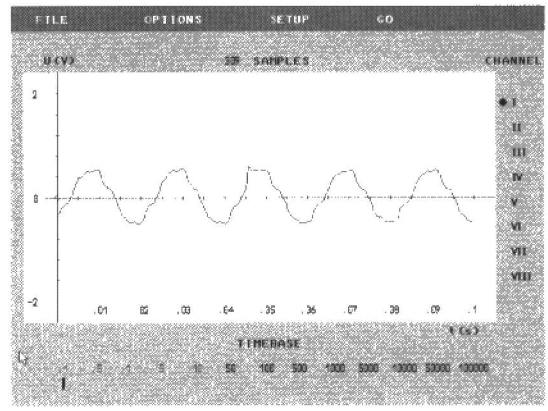


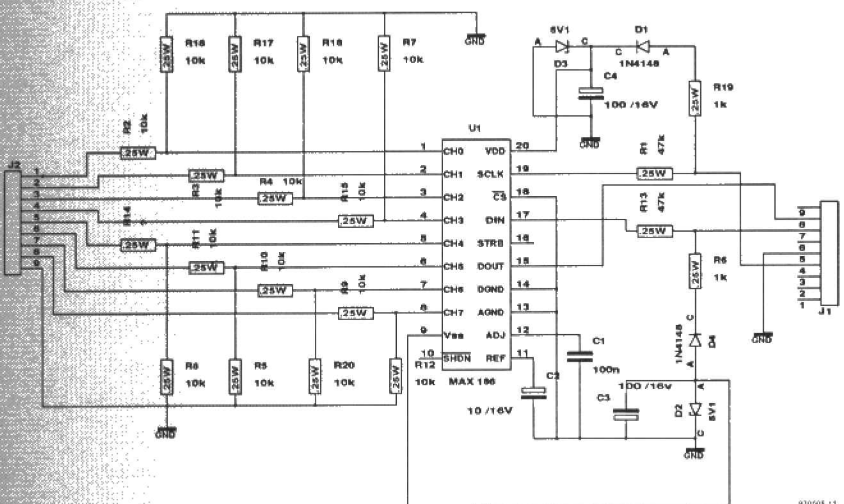


1st National Prize (Germany)

8-channel memory oscilloscope

This Competition entry consists of the QBASIC program 'AD.BAS' which controls a small 8-channel A/D converter board connected to the serial port, and a compiled program, OSZI.EXE. which presents measured values in 8-channel-scope fashion on your computer monitor.





970005-11

Technical Data

Input channels:	*8*
Scaling:	*0V to 4V or – 2V to +2V*
A/D converter:	*12-bit*
Conversion rate:	*max. 5,000 meas./s (depends on CPU clock)*
Max. error:	*1 LSB*
Power supply:	*via RS232 port*

By R. Mohrlok

The data logger program AD.BAS was written in QBASIC 4.5 and serves to read an A/D converter type MAX186 via the serial port. The program contains subroutines for the reading of eight analogue input channels. The software sets the levels on the serial interface lines, and so conveys the control bits required by the converter. AD.BAS is easily converted into a higher programming language. Information regarding important parameters may be found in the README file. AD.BAS supplies the conversion result (VOUT%) and a scale factor (UREAL). Both values are displayed by the memory 'scope program, OSZI.EXE. Extensive information on this subject may be found in the file OSZI.TXT. OSZI.EXE offers four pull-down menu selections: FILE, OPTIONS, SETUP and GO. These allow you to determine the interface (COM1 through COM4), select the measurement channel, and launch, store or retrieve a measurement. A number of display options are available. Furthermore, the measurement channels may be calibrated and given an offset. OSZI is associated with a driver for HPGL-2 compatible printers, and any IBM compatible AT computer having a VGA video card.

Hardware

The compact board (50×50 mm) designed for the converter hardware contains the 12-bit A/D converter with its internal 8-channel multiplexer. The converter is configured by signals supplied by the PC via the RS232 port control lines. Line 4 acts as a clock line, while line 7 conveys the configuration data (unipolar or bipolar). Line 8 transfers the result of the previous conversion to the computer. The converter receives its supply voltage from the RS232 interface. The input current of the analogue inputs is so small that the maximum error caused by the protection resistors equals 1 LSB.

(970005-1)

4th National Prize (Germany)

LPT test

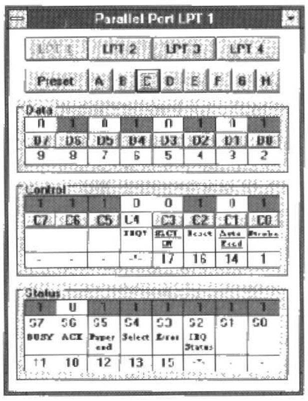
LPT test is a useful program when it comes to checking the functions of the PC's parallel printer port when it comes to developing new interface components or repairing and/or servicing PC printer ports. The program consists of an EXE, an INI and two DLL files which may be installed in any subdirectory you like.

by J. Zieschang

The PC's parallel printer port may be used as an input/output interface in combination with many peripheral components. The relevant 25-way sub-D connector at the back of the PC provides a total of three port registers: a data register comprising bits D0 through D7, a control register, C0 through C7, for controlling connected peripherals, and a status register, S0 through S7, for messages from connected peripherals to the computer. Normally, the data lines are used to inform the printer about the bit pattern for the next ASCII or control code. The validity of the data and their acceptance by the

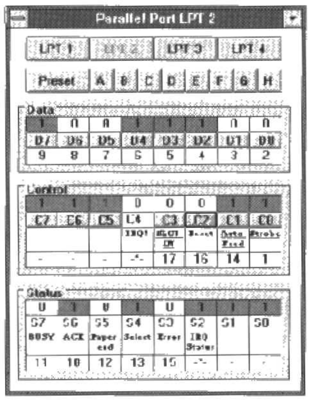
peripheral is marked by a computer-generated pulse on the *Strobe* line. Control lines *Select* and *Autofeed* are used to tell the printer to be ready for use, or do a paper feed at the end of the line, respectively. The printer may use the *Busy* line to inform the computer that it has not completed the current task yet. Similarly, it may flag *Paper Empty* to indicate that it is out of paper. The *Error* line is actuated when an error exists in the printer (or the printing process), while *IRQ* demands an interruption of the printing operation.

The parallel port is freely usable for one's own applications, provided you realize that the status lines may only be used as inputs, and the control lines, as outputs. On most older computers, the data lines may only be used as outputs, while on newer models they may be used as inputs also. Consequently, LPT Test not only reads the status information, but also the data port, because it can be manipulated by (mod-



ern) peripherals. The indication of the current values in the ports is by means of 1's and 0's on the display. All inputs are continuously read and displayed. The outputs may be switched as desired. The read-back rate is CPU-dependent, and works out at about three read operations per second using a 486 processor running at 25 MHz. This sort of speed is ample for most, if not all, hardware tests.

A test adapter may be made

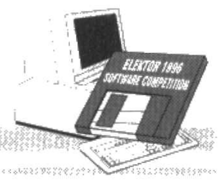


from a 25-pin sub-D plug on which any connections may be present between the data lines and the status lines. If, for instance, data line D0 (Pin 2) is wired to status line S5 (pin 12), the relevant output may be toggled by clocking on the D0 button. This copies a logic level to pin 2 of the sub-D plug (D0) and from there to the Paper Empty input (pin 12) of the status port (S5). The resulting colour changes in the control fields D0 and S5 then indicate the presence of the connection. Similarly, you may use the software to switch LEDs or opto-isolators.

To invoke one of the presets, simply activate one of the buttons A through H. For this arrangement, eight separate preset registers are provided for each interface LPT1 through LPT4. Storing a setting is accomplished by means of the Preset button, followed by your selection of the preset register, A through H. The action of storing the setting in the INI file is acknowledged with a message.

The selection of the port to be tested (LPT1 through LPT4) is accomplished via the upper buttons. The currently active port is marked in bright gray and also indicated in the header line. The program may be called several times, enabling you to test several ports (virtually) at the same time.

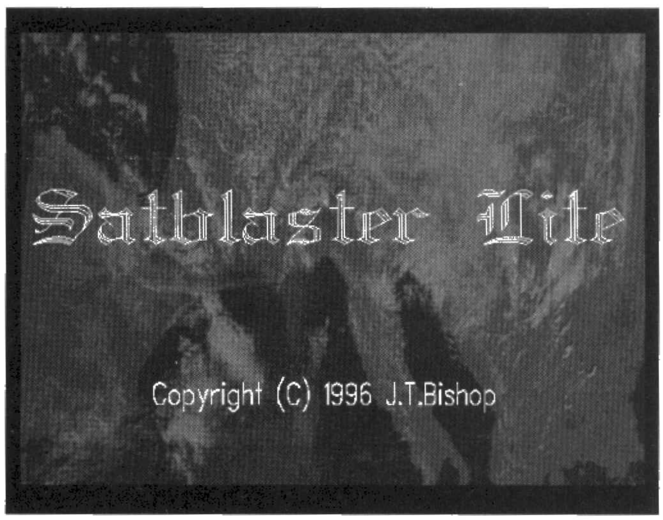
(970005-2)



2nd National Prize (UK)

SatBlaster Lite

The program's function is to convert the output of a VHF weather satellite receiver to a displayable picture, using only a Soundblaster soundcard. The program has been successfully used to display visible and infra-red cloud cover pictures transmitted by the American TIROS-N series polar-orbiting satellites using the APT (automatic picture telemetry) format. The Russian satellites are not supported as yet.



By J.T. Bishop

A 'Mapsat' VHF satellite receiver obtained from Maplin Electronics was used (this particular low-cost model is alas no longer available, but there are other receivers and antennae on the market). This image is included on the enclosed disk. Copyright of all satellite images presumably rests with the NOAA.

The program is written in Borland Turbo C V.2.

To try out the program, copy all the files to a directory on the hard disk. Make this the current directory, then type 'sb' from the DOS prompt. After the copyright message, you will be presented with a menu. The choices are:

1. Enter filename. The required filename should be entered: the extension, if provided, will be ignored. The default filename is 'demo1'. Wave files must have the extension '.wav'. Try entering 'demo2' to display the other .sat files on the disk.

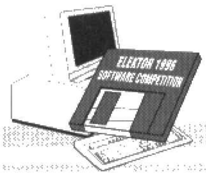
2. Convert a file from wave format. This reads in the specified .wav file and converts it to a pixel bitmap file of the same name but with extension ".sat". The wave file may be produced with a suitable utility provided with the sound card (I used 'Creative Wave Studio', a Windows-based program supplied with my Soundblaster-16). The recording format must be 8 bits mono with a sampling rate of 44,100 Hz and no compression. This is the only format recognised by the program at present.

3. Display Sat File. This will display the bitmap (.sat) file on the screen. Either the visible or the infra-red image may be displayed. Press 'V' to display visible, 'I' to display infra-red. The brightness and contrast (gamma correction) of the picture can now be adjusted to bring out the detail. Press 'B' followed by a number in the range 0 to 256 (followed by return) to set the black level. 'G' is used likewise to set the gamma or contrast. Pressing 'D' followed by a number in the range 0 to 3 enables the orientation of the picture to be changed. The picture is redrawn to show the effect of

the new settings. Once you are satisfied with the picture, you may save it by pressing 'Escape', when you will be asked whether you wish to save the changes. Note that no information is lost by doing this, the picture is merely saved with additional information about alignment and contrast etc.

4. Edit Sat file. This allows the picture to be 'cleaned up'. Noise during reception may have caused the picture to lose synchronisation and 'slip', so that some parts of the picture are out of alignment with the rest. To demonstrate this feature, a suitable file is provided on the disk called 'demo2.sat'. Pressing the up/down arrow keys causes the picture to be displayed/deleted one line at a time. When an offset line is encountered, it may be shifted to the right or left, using the appropriate arrow key, until it lines up with the rest of the picture (this unfortunately requires good eyesight!). Subsequent lines will then be shifted by the same amount. The visible and infra-red images may be corrected separately (they are displayed side by side (it is up to the user to ensure he is editing the right one). The infrared image has narrower synch-tone bars to the left of it). Type 'I' to select infra-red, 'V' to select visible. Changes may be saved as with the display option.
5. Display grey scale. This is provided for the user to adjust the brightness and contrast controls of his monitor.
6. Quit.

Hard copy may produced by typing 'GRAPHICS DESKJET' (or the type of your own printer if not a deskjet) before running Satblaster, then pressing the print screen key when a suitable image is being displayed. (970005-3)

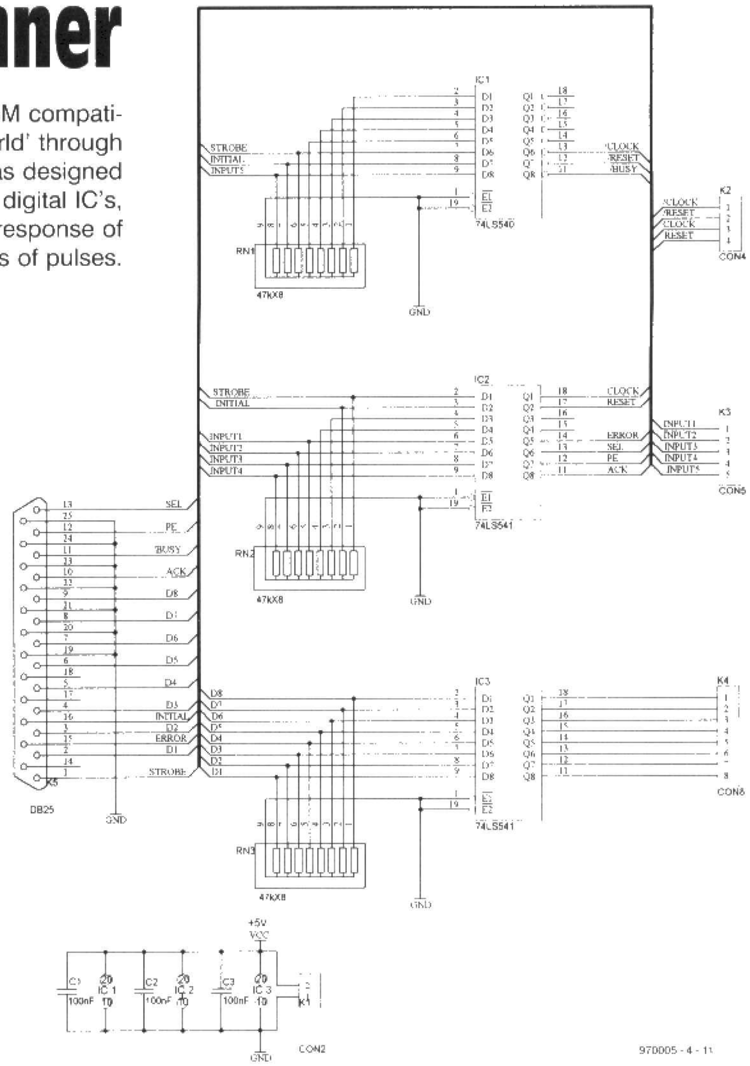


3rd National Prize (UK)

logic scanner

This project is a Logic Scanner based on an IBM compatible PC that communicates with the 'outside world' through the parallel printer port. The Logic Scanner was designed for testing and control of digital constructions, digital IC's, devices etc., where it is required to record the response of a certain test object to a series of pulses.

By Anthimos Spartalis



The only system requirements are an IBM compatible PC with DOS 5.0 or greater and a typical parallel port (not necessarily an extended type), and the interface card.

The system is composed of two subsystems: an application program and an interface card. The application consists of three subsystems: a programmable 8-bit logic generator, a small 5-bit logic analyzer (allowing it to be used by PC XT/ATs also) and a logic function generator.

The program is launched by typing 'LOGICSCN.EXE' from the DOS prompt The program will allow you to choose the address of the parallel port to which the hardware is connected. Optionally, choose an OUTFILE (the file that contains the output pulses) in an ascending order (0-255) or, if you want, a file with all zeroes.

The application menu offers the following options: Edit OUTFILE, Record INFILE, Display OUTFILE/INFILE, Logic Equation Generation, Quit, Increase/decrease delay between output pulses, and OUTPUT PULSE DELAY: _> ms. (output pulses are the pulses from the PC to the tested construction).

The interface card has five connections: Power Supply (K1, 5V), Control Signals (K2, CLOCK/RESET), Input Signals (K3, 5-bit), Output Signals (K4, 8-bit), and Parallel Port (DB25 to printer port). The control signals may be used to drive and initialize the device under test, if necessary. CLOCK and /CLOCK are strobe pulses which enable the OUTPUT signals to change. Similarly, RESET and /RESET initialize the circuit under test when the program is started, or the PC is rebooted.

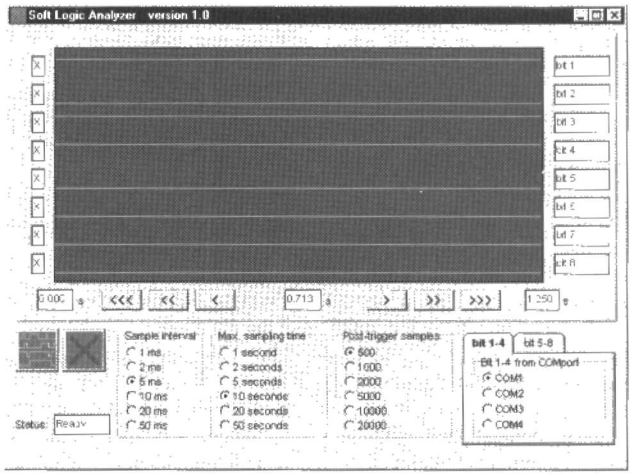
The cable between the parallel port and the interface card should not be longer than about 2 metres, especially when a fast computer is used, and the PULSE DELAY is set to minimum. (970005-4)

Note: The printed circuit board artwork for this project may be found on the Software Competition CD-ROM.

2nd National Prize (Netherlands)

Slogan

Slogan enables a regular PC to be used as an 8-bit Logic Analyzer. The input signals are read via two COM ports. The analyzer program runs under Windows, and features an extremely user-friendly user interface. Although the maximum sampling frequency is not particularly high, Slogan may prove very useful for the analysis of relatively slow signals as used for, say, mechanical controls and stepper motors.



By N. Koper

The user interface of this prize-winning program was developed with the aid of the RAD tool Delphi 1.0. The program section which is responsible for the data sampling was written in assembly language. Data bits are read from the modem registers belonging with the selected COM ports, whereupon the desired four bits are extracted. This requires the data under test to be applied to the CTS, DSR, RI and CD terminals of the serial port, while the GND pin is used as the common ground connection.
The standard timer in the PC is reprogrammed to enable a sampling rate of 1,000 samples per second to be achieved. Because the software directly controls certain hardware blocks, conflicts may arise with other software or hardware attempting to control the same hardware. Because of this, it is recommended to close all other Windows programs before starting Slogan.

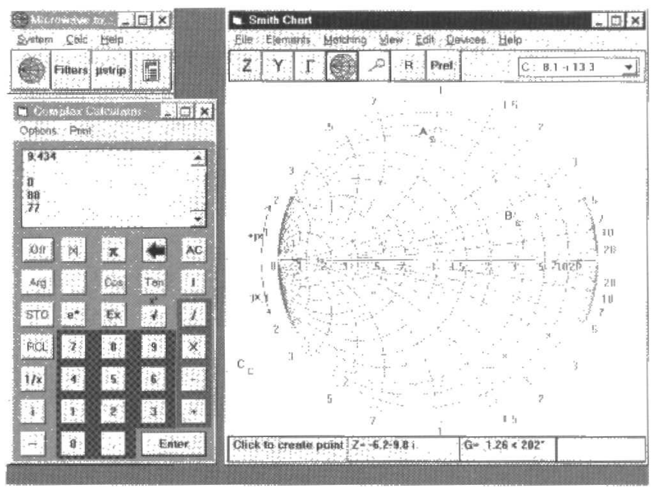
Operation

The electrical signals on the COM port must have levels between +12 V and −12 V to prevent damage to the inputs.
The choice of the desired COM port is easily made via the user interface.
The trigger-bit patterns are entered to the right on the screen (0, 1 or X = don't care). Next, you have to enter the sampling interval, the number of post-trigger samples and the maximum sampling time. Note that the latter parameter has to be larger than the product of the sampling interval and the number of post-trigger samples.
Samples are taken after pressing the 'start' button. A status indication is visible in the left-hand bottom corner of the screen. The indicators are activated by: Init (after starting), Busy (while waiting for the trigger word and during sampling), Ready (on successful reading of a data stream) or No Trigger (if the trigger pattern did not occur during the set maximum time, or when insufficient time was left to record the desired number of post-trigger samples).
After reading the samples, the reference timing instant (0 s) equals the point at which the trigger pattern was recognized for the first time.
The arrow keys at the bottom of the analyzer screen may be used to scroll through the data. Using the mouse you may click anywhere in the analyzer screen to bring up the relevant timing information. (970005-5)

1st National Prize (France)

Microwave Tools

Microwave Tools is a set of tools aiming to help the RF and microwave designer in several areas of his work. The interactive Smith chart provides a way to visualise impedance matching through the entire circuit. The filter design window helps to design the main filter topologies by calculating the filters coefficient, and proposing the components values for several different practical realisations. The other tools provided are a microstrip synthesis/analysis window, and a complex-number calculator.



By Fabrice Maingot

The interactive Smith chart. This tool draws a Smith chart with the possibility to place impedance, admittance or reflection coefficient points and visualise the impedance travel on the chart.
- Placing points:

The user just places the points on the chart by clicking at the desired location, or by entering the impedance, admittance or reflection coefficient value with the keyboard. Then, elements may be added in series or in parallel to visualise and calculate the new impedance. These elements may be pure reactances (like capacitors or inductors), transmission lines or open or shorted stubs.
- Placing fixed and calculated elements:

The elements are selected via the main menu, and a window is then displayed to enter the necessary parameters for the fixed elements. The user may

also place parameters of which the program will calculate the possible value(s) for a given condition. A choice is provided if several values are possible. This condition may be the intersection with a constant reactance or constant resistance value, allowing these to travel along the different circles of the chart in order to join the centre or any other point.
- Options and special features: The user may zoom into any section of the chart in order to improve the definition in a defined region, or may just magnify or reduce the scale. The characteristic impedance of the chart (Z_0) is defined as 50 Ω by default but may be changed in the Preferences window. The admittance chart may be displayed or hidden by clicking on the admittance button, or in the preferences window. The position of the cursor is displayed as real-time impedance, at the bottom of the window. The user may also select reflection coefficient, admittance and equivalent component as real-time displays.

Automatic impedance matching:
Two kinds of impedance matching networks may be calculated: single and double stub.

Calculations on active devices S parameters:
The S-parameter files (in Touchstone S2P format) of a transistor or 2-port device may be loaded in order to plot input and output stability circles, and noise circles. The S-parameters may be also entered or modified manually by the user.

The filter designer tool
The filter designer tool enables you to calculate the order and the parameters of a passive filter according to specifications given regarding cut-off frequencies, pass-band ripple, out-of-band attenuation, and so on. It only supports Chebycheff and Butterworth types, and low-pass mode.

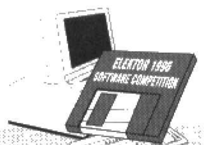
The Microstrip Synthesis/Design tool
This form is made to help calculate the physical parameters of a microstrip line, given its characteristic impedance, or the reverse. It may be used in two modes: Synthesis or Design. First enter the physical properties of the substrate (dielectric constant and thickness, metal thickness, height of cover). Then either enter the impedance (and required phase shift), or the width (and length), and press the Calculate button.

The complex Calculator
This is a small tool, simulating a pocket calculator with complex numbers management capabilities, and using the HP calculators notation system. For example, if you want to calculate 2 + 3, just do:

(2) (Enter) (3) (+) (instead of 2 + 2 = ...).

To enter complex numbers, type
(x) (+) (or (--)) (y) (i) (Enter).

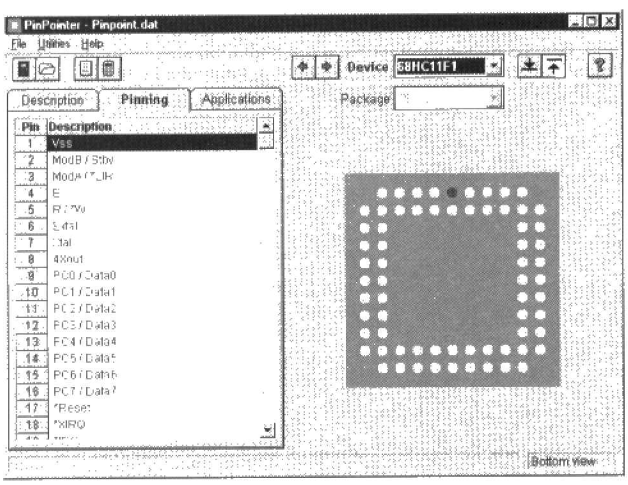
The complex calculator may be launched from several forms of the Smith chart tool, in order to enter values that are results from a calculation. (970005-7)

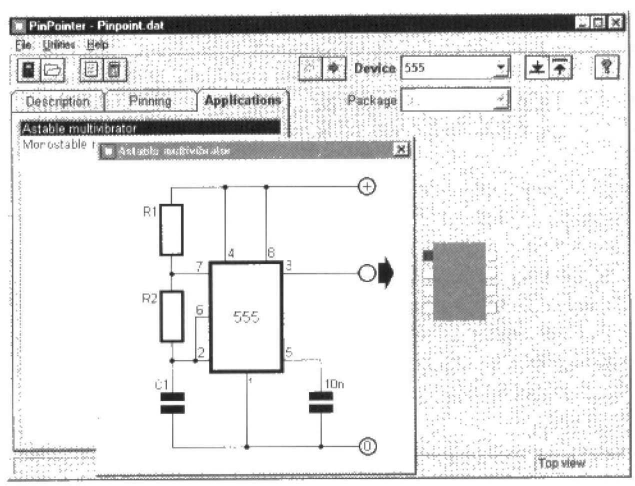


3rd National Prize (Netherlands)

Pinpointer

This program provides assistance in searching electronic component connection data. For each component searched for in the database, Pinpointer shows the case, the functions of the connection terminals, and, in some cases, a short comment and an application circuit. The great thing about this program is that it is fairly easy to add information to the database.



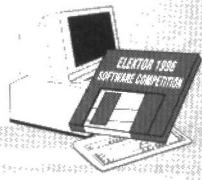


By S. van Hulle

Like Slogan, the other prize-winning Dutch competition entry described on these pages, Pinpointer was written in Borland Delphi 1.0. Pinpointer is an easy to use Windows program. Initially, the author wrote Pinpointer for looking up pin-out information on PLCC and DIL enclosures only. With some creativity, however, you may add just about any component shape you like.
A special feature of the program is the intelligent structure used to build the enclosure types. You only have to enter the type and the number of pins of a particular component, and the program draws the associated enclosure. With DIL ICs, the number of pins is equally distributed across the two long sides of the chip, while a distribution across all four sides is applied for PLCC devices (using a distribution algorithm designed by the author).
In addition to the component shape (where a selection is available between top view and bottom view), short pin-function descriptions are given in a separate box. It is also possible to request a short description of the IC.
A nice bonus is the option to link the component to one or more application examples. Being ordinary bitmap files, these examples are easy to make. Finally, the Windows Calculator and Notepad may be called directly from the program.
The database has a very simple structure, consisting of a text file which contains all data (case shape, connections, optional schematic) arranged in sequential fashion.
The current version of the database is not too large, compris-

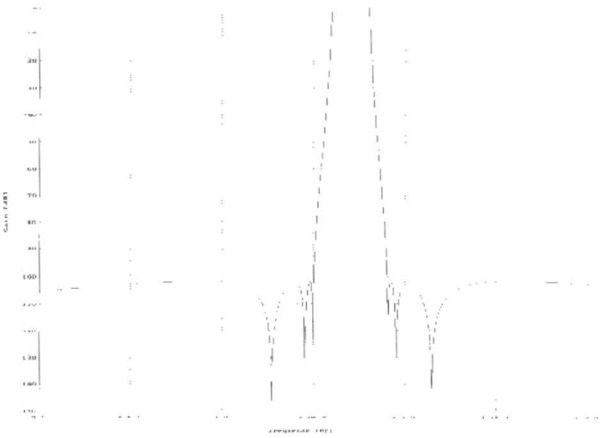
ing only five components. Thanks to the simple structure, however, it should not be too difficult to extend the program to personal requirements. Hey, there's an idea for a Mini Contest: *who writes the most extensive or most interesting database for this program?* What about all components used in *Elektor Electronics* project over the past years?

(970005-6)



4th National Prize (France)

passive filters



Designing, implementing and analyzing filters is a very difficult task for many electronics engineers. In fact, filter technology is one of the most complex aspects of analogue electronics. The program written by Mr. Vouilloz provides a helping hand in such situations, farming out all calculation work to the computer.

By A. Vouilloz

In electronics engineering, there are only two options when it comes to designing a filter for a specific application: either you calculate the respective component values by hand using filter theory formulas, or you resort to look-up tables providing component values. The first option requires a lot of time (and experience), while the second is often restricted to known filter types such as Butterworth, Chebychev, etc. Well, the combination of a computer and a specially designed program may save you a lot of work.

Features

The program offers two basic functions: dimensioning and analyzing passive filters. It may be used, for example, to design a loudspeaker, or the output filter of a an RF amplifier, to mention but two applications. The following filter types may be designed by the program:

- Bessel
- Gauss
- Chebychev
- inverse Chebychev
- Butterworth
- Legendre
- elliptic

In addition to these, it is possible to compute a group delay compensation for a known filter, as well as three types of phase-shifting networks.

The program is available in two languages: English (SYNFIL.EXE) and French (CREERFIL.EXE). Having launched the program you first select the filter type, then the desired band (high-pass, low-pass, etc.), the minimum slope, etc. The results are shown in the form of three characteristic polynomials. Having calculated the associated poles, the practical dimensioning of the filter is shown.

After the calculations, the filter characteristic may be viewed in graphical form: amplitude, phase characteristic, group delay and transient behaviour. All these results may be stored in a file, or copied to a printer. Another program is available on the disk. ANAFIL.EXE allows a filter (or a four-pole network) to be analyzed which was designed using SYNFIL.

Computer requirements

To be able to use the program, you need a computer with a 486 CPU or better (and a coprocessor if you have a 486SX). Almost any video card may be used, from CGA and Hercules to VGA. The program runs under DOS 3.1 or higher, or in a DOS box under Windows 95.

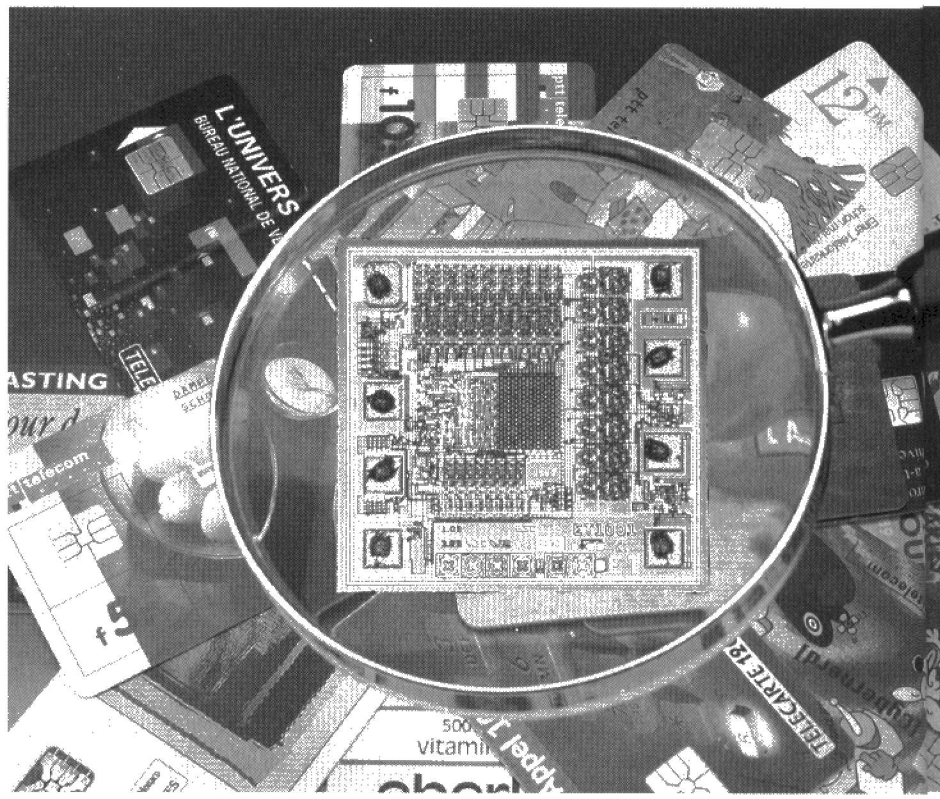
(970005-8)

focus on: chip cards

an exploratory look at intelligent telephone cards

Chip cards come in a wide variety, and their contents seems to exert a strong attraction on many electronics enthusiasts. Disposable telephone cards (some of which have become collector's items!) are a great starting point for many experiments in manipulating the electronics contained in the plastic. Some experimenters have successfully turned expired phonecards into electronic ID cards for use in controlled-access systems. Others, many on the 'hackers' front, use them to find weak spots in systems which have been declared totally secure.

By Patrick Gueulle



Whatever way you want to start examining the contents of an intelligent telephone card, you have to be able to communicate with the chip it contains. Communication, in turn, requires a basic knowledge of the signals transferred between the card and the reader unit. This knowledge, eventually, brings you to the actual thing: the contents of the memory on the card.

First: the hardware:

A chip card is a plastic card having the same size as a credit card. A very thin silicon chip is secured into the plastic carrier at an accurately determined position.

Awaiting the arrival and standardization of the contact-less chip card, the communication with the reader unit is accomplished via six, seven or eight flat contacts whose position is standardized.

The pin numbering of the chip contacts is shown in **Figure 1.** Actually, the proper term for the unit is 'micromodule'.

Although chips with eight contacts are still found occasionally, most modern cards have only six contacts, the ones designated ISO4 and ISO8 having disappeared.

Contact number ISO5 is always easy to locate. Representing the ground connection, it extends into the centre of the micromodule.

On the card, the chip may have two positions. The 'ISO' position shown in **Figure 2** is the most common these days, as it is the only one expected to survive in the long term.

The AFNOR variant shown in **Figure 3** is now obsolete, being a remnant of early telephone card series issued in France. Millions of these cards are still

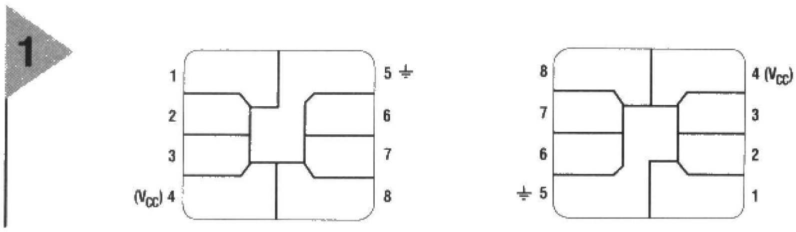


Figure 1. Terminal functions for ISO and AFNOR hip cards.

around, however. Not surprisingly, most commercially available card readers have two contact groups: one for ISO cards, and one for AFNOR cards. The contact groups are, incidentally, simply connected in parallel inside the cardreader.

Just like any other electronic component, a chip card has to be powered. The main supply voltage (V_{cc}) is +5 V. This is applied to contact ISO1.

The oldest cards around (manufactured in NMOS technology) require a second supply voltage, V_{pp}. Applied to contact ISO6, V_{pp} is normally at +5 V, or at +21 V during write operations.

With so few contacts left on the chip, it goes without saying that data is exchanged in serial fashion.

The ISO7 contact is reserved for data input/output (I/O). The use of the remaining contacts differs between card technologies.

Here, we limit ourselves to examine cards which are called 'synchronous', which covers disposable phone-cards. After all, these cards are really just protected memory units. By contrast, asynchronous cards contain a microprocessor. These cards are used for much more complex systems requiring a higher degree of security, such as pay-TV, credit cards and electronic wallets.

Synchronous chip cards operate in sequential fashion, using an internal address counter which always points at the bit which is to be read or written.

These 'micro-instructions' are written to the card via two or three contacts, one of which (in principle, ISO3), acts as a clock.

Virtually all telephone cards obey one of two communication protocols:

- the 'three-wire' protocol based on French technology (currently the most widely used in the world);
- the 'two-wire' protocol based on German technology (this is receiving gradual acceptance in Europe: including the UK, Holland, Switzerland, etc.,

Even a cursory look at the tables in **Figures 4 and 5** reveals the vast differences between these two protocols, which is another way of saying that they are incompatible.

None the less, the general procedure to launch a read operation on a card is largely identical for both protocols: first, the card is powered, and then, a 'RESET' micro-instruction is issued by the reader. Next, the first memory bit may be read via card contact ISO7.

Note, however, that there are cards (notably of the 2-wire type) which require a pull-up resistor to be present between the ISO7 contact and V_{cc}, because their output is of the 'open drain' type. In general, a resistor value between 5-kΩ and 10kΩ is sufficient.

In order to access the *n*th bit of the memory, the reader has to issue *n* 'UP' micro-instructions before it is able to read the relevant bit via the ISO7 contact.

Since no provision is made to decrement the address counter, access to any 'earlier' memory cell calls for a RESET and the relevant number of UP instructions to arrive at the desired address. So, bits are read in their original order for most of the time.

Under certain conditions deter-

Figure 2. On these phone cards, the chip is in the ISO position.

Figure 3. Two AFNOR compatible phonecards.

Figure 4. The 'French' protocol.

ISO 6: Vpp (21V)
ISO 7: data output
ISO 8: fuse (do not use)

ISO 2:	ISO 4:	ISO 3:	micro-instruction
0	0		RESET
0	1		UP
1	1		PROGRAM (0→1)

Figure 5. The 'German' protocol.

ISO 6: not connected
ISO 7: data

ISO 2:	ISO 3:	micro-instruction
1		RESET
0		UP
	0	PROGRAM (1→0) link these two sequences
0		

mined by the security logic implemented on the card, one specific instruction, PROGRAM, allows a card to be written to: that is, a 0 changed into a 1 on 'French' cards, or a 1 into a 0, on 'German' cards.

AND THEN: SOFTWARE

If different communication protocols are used for cards of the French and German type, then what about their memory contents?

A first-generation French phone card ("TeleCarte" in French) contains nothing but a 256-bit EPROM. Although all of these bits may be read, only the first 96 may be programmed by the factory because they are protected by an on-chip fuse (at the ISO8 contact) which is blown at the end of the production process.

This group of 96 bits is unique for each individual card: it contains a 'serial number' and an 'authentication message'. These two pieces of information allow each individual card to be recognized. Although the first and foremost aim of this protection is, of course, to prevent card cloning, the system also allows faulty cards to be detected.

This unique matrix is, of course, a godsend for anyone wanting to build, say, an electronic lock which only recognizes a few authorized cards. All you have to do is make the reader perform a check on the 96 bits. Bit numbers 8 through 15 in this block provide the 'application code' of the card. This code may have the hexadecimal value 03, 04, 05 or 06 for a French Telecard, while any value greater than or equal to 80 indicates a different application. The story behind this is that France Telecom has succeeded in forcing chip card manufacturers to pre-program bit 8 on cards intended for all other customers.

The entire area from location 96 through 255 is used for automatic counting of phone billing units. Initially, all bits are at 0, and these are replaced with 1's at a rate of billing units 'consumed' as you phone away.

In theory, the capacity of such a card would be 160 units. In practice, however, 10 units are 'burned' by the card factory for testing purposes, limiting the credit value of cards based on this technology to 150 phone billing units. In France, these cards have a value of 5, 50 or 120 units, which means that each expired (empty) Telecard still contains a number of bits which may be changed from 0 to 1 in the course of experimental manipulations.

Figure 7, for example, shows the memory contents of a new, unused 50-units phone card. The contents of the same card, but then empty, is given in **Figure 8** (note the 8 last bits which remain at logic 1 although all the card's worth has been used up). **Figure 9** shows how an appropriate piece of software is capable of deciphering the 256 bits on the card, and turn them

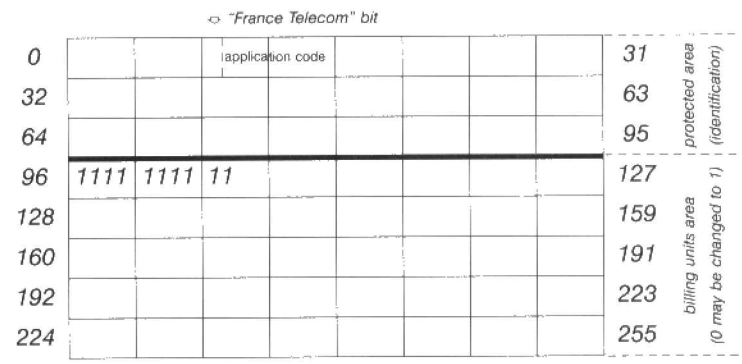


Figure 6. Memory structure of a French Telecard.

Figure 7. French Telecard, 50 units, unused.

1100	0011	0000	0101	0101	1001	0001	0100
1100	0011	0010	0010	1000	1000	0011	0011
1011	1111	1110	1110	0001	0000	0000	0110
1111	1111	1100	0000	0000	0000	0000	0000
0000	0000	0000	0000	0000	0000	0000	0000
0000	0000	0000	0000	0000	0000	0000	0000
0000	0000	0000	0000	0000	0000	0000	0000
0000	0000	0000	0000	0000	0000	0000	0000

Figure 8. The same Telecard, empty.

1100	0011	0000	0101	0101	1001	0001	0100
1100	0011	0010	0010	1000	1000	0011	0011
1011	1111	1110	1110	0001	0000	0000	0110
1111	1111	1111	1111	1111	1111	1111	1111
1111	1111	1111	1111	1111	1111	1111	0000
0000	0000	0000	0000	0000	0000	0000	0000
0000	0000	0000	0000	0000	0000	0000	0000
0000	0000	0000	0000	0000	0000	1111	1111

Chip Type:	*Texas or EEPROM*
Family Code:	*05 (Phonecard)*
Serial Number:	*59142288*
Authenticity Message:	*33EE*
Programming Parameters:	*1 (50ms/21V)*
Service Code:	*0 (disposable card)*
Total Value:	*06 (50 units)*
Used Up:	*50 units*
No Remaining Credit	

Figure 9. Interpretation (by a special program) of the data read from the card in Figure 8.

Figure 10. Memory counter of an empty Spanish Telecard, with an original worth 1,000 ptas.

1010	1011	1000	0011	1111	1111	1111	1111
0101	1010	0000	1001	1011	0111	0001	0101
0001	0100	1000	1010	0001	1110	0010	0010
1111	1111	1110	0010	0000	1000	0100	0001
0000	0100	0001	0000	0100	0001	0000	1000
0100	0000	1000	0100	0010	0000	1000	0001
0000	1000	0010	0110	1010	0001	1001	0010
1000	1010	0100	1001	0010	0100	1010	0001

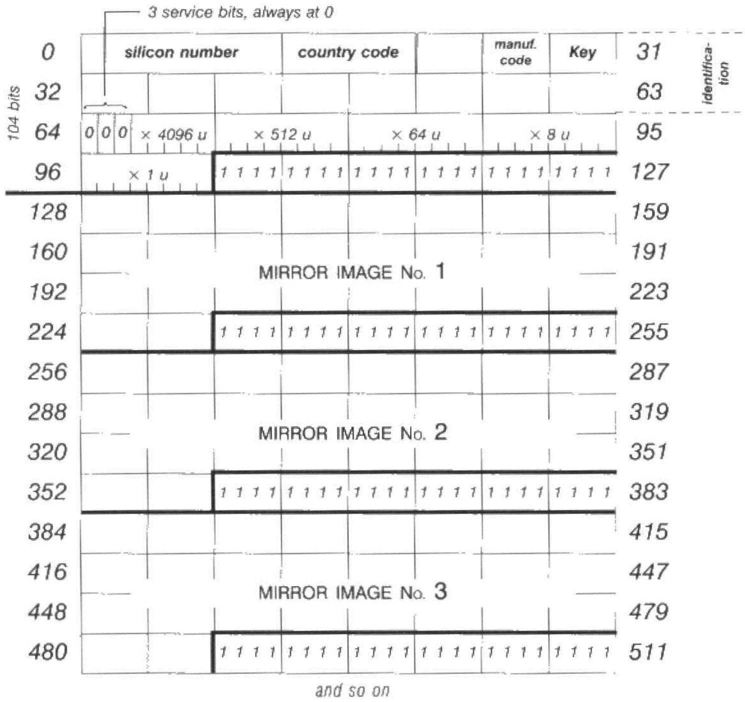


Figure 11. Memory structure of a German phonecard (old version).

Figure 12. Read result of the 512 bits in an empty German phonecard (old version). The same area of 128 bits appears four times.

1111	0010	0010	1111	1111	1111	0100	1010
1110	0010	1100	0000	1100	1110	0100	1100
0000	0000	0000	0000	0000	0000	0000	0000
0000	0000	1111	1111	1111	1111	1111	1111
1111	0010	0010	1111	1111	1111	0100	1010
1110	0010	1100	0000	1100	1110	0100	1100
0000	0000	0000	0000	0000	0000	0000	0000
0000	0000	1111	1111	1111	1111	1111	1111
1111	0010	0010	1111	1111	1111	0100	1010
1110	0010	1100	0000	1100	1110	0100	1100
0000	0000	0000	0000	0000	0000	0000	0000
0000	0000	1111	1111	1111	1111	1111	1111
1111	0010	0010	1111	1111	1111	0100	1010
1110	0010	1100	0000	1100	1110	0100	1100
0000	0000	0000	0000	0000	0000	0000	0000
0000	0000	1111	1111	1111	1111	1111	1111

into a maximum amount of meaningful data. Some countries (in particular, Spain and the Croatian Republic) use a much more intricate 'counting scheme' which allows the apparent limit of 150 units to be exceeded. Without going into details, this result may be explained by the fact that certain bits represent a value of several billing units, as illustrated by the example in **Figure 10** (memory contents of an empty Spanish phone card with an original value of 1,000 ptas).

Developed a couple of years after the French version, the German phone card ("Telefonkarte") has been able to benefit from a more modern technology, namely CMOS EEPROM.

However if you say EEPROM you also say 'possibility to erase and rewrite'. Also, the basic operation of these cards is radically different from the early French ones.

The table shown in **Figure 11** shows that the basic German phone card is set up around a memory of 104 bits. If you attempt to read bits 104 through 127, you invariably get 24 logic ones. From address 128 onwards, a mirror-image is found of the contents starting at 0. In other words, the address counter returns to the start in cyclic fashion. The first 64 bits may be compared to the first 96 on the French phonecard, in the sense that they also contain card identification data.

Bits 0 to 11 contain a 'silicon number' which is programmed in the chip when it is manufactured. This number may be the same in a (very) large number of cards.

The next eight bits are, in principle, identical for all cards from a nationwide operating telephone company (FF_h in Germany, $7F_h$ in Holland, BF_h in Guernsey, $2F_h$ in Great Britain, etc.).

Bits 24 to 27 identify the card maker, for example, 0_h for ORGA, 8_h for Giesecke & Devriendt, 4_h for ODS, C_h for Gemplus, 2_h for Soliac, 9_h for GPT, etc. For really unique data, however, we have to look in the area reserved for the billing units counter. This area is effectively divided into five counters: four of eight bits, and one of

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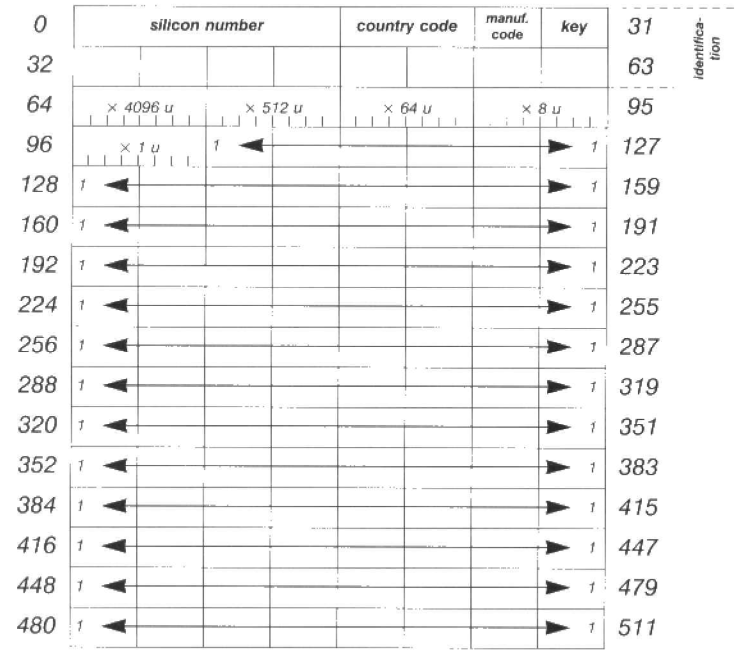

Figure 13. Eurochip memory structure.

five bits, whose function may be likened to that of an abacus. Each billing unit (or credit) you use up in a public phone booth is accounted for by a logic 1 changing into a 0 in the 'units' counter occupying the address range from 96 to 103. Once this area is full (in other words, when its eight bits are at logic 0), a bit is set to 0 in the next counter (the ×8 units one). This operation also resets the eight bits in the 'units' counter to logic 1. In the same way, a 'carry-over' is written into the ×64 units counter once the 8 units counter is emptied, and the same again with the last counter, which counts by 4,096 units.

Manufacturers of integrated circuits for use on chip cards always state that this 'counting scheme' allows a phone card to be produced representing a total of 20,480 phone billing units with just 37 bits (8×8×8×8×5 = 20,480).

A little arithmetic reasoning however reveals that the above is a gross error which no-one seems to have noticed for years! In actual fact, the capacity of the counter array is 25,160 units. Whatever the exact number, that's far more than the 160 units of a 256-bit EPROM card, and it real currency units like pence, cents or pfennigs to be counted directly, and not just those strange 0.80 FF units as in France. This advantage allows phone companies to charge calls depending on the actual duration (even down to seconds if so desired). On the down side, this technology has an Achilles heel in that it is possible for a user to re-charge his card himself, and so telephone for free. To prevent this kind of fraud, the card providers pre-load the counters in the factory, so that the 'units' which may be used up again are an exact match of the value printed on the card. So, on an 'empty' German phonecard (**Figure 12**), all bits of all counters are at 0.

This simple security measure was, apparently, not sufficient, witness the proposals for a more sophisticated technology designated 'Eurochip'.

Figure 13 shows that the first 128 bits are compatible with those we just examined. Only instead of three 'mirrored' areas, the memory area covering bit 128 to 511 contains only ones, interspersed with the occasional 0 as illustrated in **Figure 14**.

As you might well imagine, this area has a definite function in an encrypted security mechanism as, for instance, used in safes.

Top-secret for obvious reasons, this mechanism is based on the 'challenge-response' principle. The intention is to fit every public telephone booth with a security module in the form of a card containing a miniature chip. This module frequently sends a random number to the Telecard. This number is used by the card to perform a secret calculation.

Once returned to the security module, the result of the calculation is supposed to enable the module to run an error-free check on the authenticity of the card, and the financial transaction in progress.

There are now grave doubts whether the French T2G second-generation Telecard will ever make it to commercial use. This card employs a related mechanism, although it remains compatible with the 'first-generation' cards which are currently used in France.

At this point many Frenchmen will wonder if the arrival of a single European phone card, that is, one which is usable across all European borders (in as far as these exist), will mean the end of many years of pioneering research in their country. (960114)

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Figure 14. Read result of the 512 bits in a Eurochip-based phonecard. The first 128 bits are compatible with the older versions.

1101	1000	0010	1111	1111	1100	0100	1010
1010	1010	0011	0100	1100	0001	1010	0110
0000	0000	0000	0000	0000	0000	0000	0000
0000	0000	1111	1111	1111	1111	1111	1111
1111	1111	1111	1111	1111	1111	1111	1111
1111	1111	1111	1111	1111	1111	1111	1111
1111	1111	1111	1111	1111	1111	1111	1111
1111	1111	1111	1111	1111	1111	1111	1111
1111	1111	1111	1111	1111	1111	1111	1111
1111	1111	1111	1111	1111	1111	1111	1111
0111	1111	1111	1111	1111	1111	1111	1111
1111	1111	1111	1111	1111	1111	1111	1111
1111	1111	1111	1111	1111	1111	1111	1111
1111	1111	1111	1111	1111	1111	1111	1111
1111	1111	1111	1111	1111	1111	1111	1111
1111	1111	1111	1111	1111	1111	1111	1111

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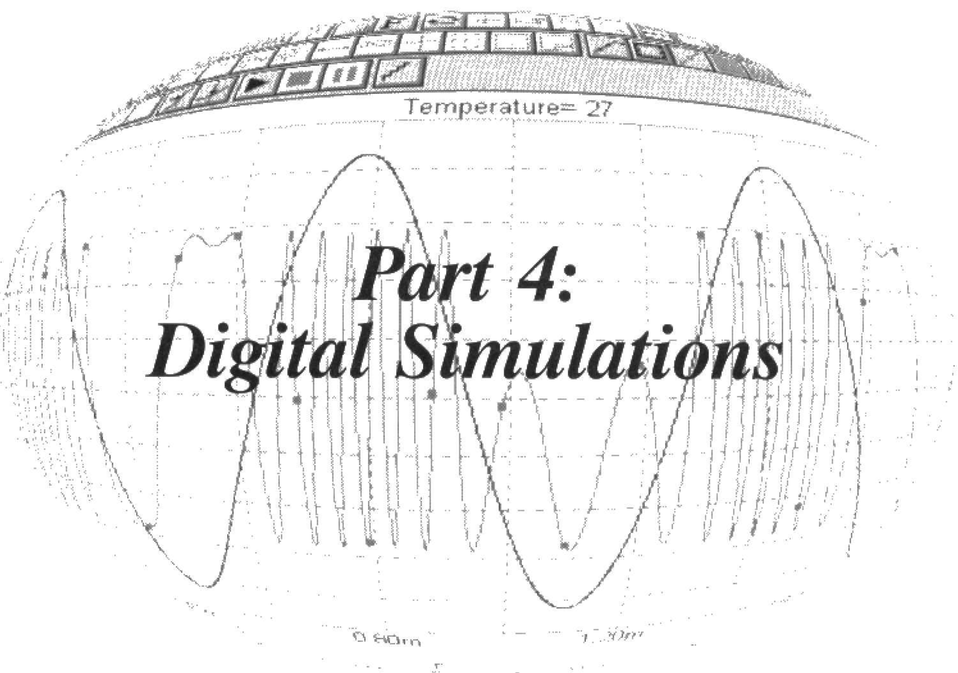

Part 4: Digital Simulations

The digital circuits supplied as demonstrations with a simulator are usually intended to impress the prospective user by their complexity. Only people used to scanning digital schematics can comprehend them. In this part of the article we will help the beginner to get the feel of digital networks.

Spectrum Software (UK) trading as Rainbow Software have advised us that a **fully functional** version of Micro-Cap V is available to any of our readers via their Internet WEB site. The URL of the WEB is

http://www.micro-cap.co.uk

Readers will be able to instantly download the software **free of charge**.
Rainbow Software also provide a support WEB for **all** Micro-Cap users.
Readers not on the Internet can contact Rainbow Software at
Ash Lea House
Oldfield Road
Bromley, Kent BR1 2LE
Telephone 097 328 8242
Voicemail/fax 0181 295 4500
E-mail: rainbow@micro-cap.co.uk

By Owen Bishop

AN EASY START

We begin with something very simple; one digital signal generator sending its one-bit signal to one logic gate (see **Figure 25**). MC5 refers to a digital signal generator as a Stimulus Generator. Several are available, with 1, 2, 3 or 4 outputs. We need a 1-bit output, so click on Components → Digital Primitives → Stimulus Generators → Stim1. The Component window lists 7 statements. The first, FORMAT, refers to the way the bits are formatted (or grouped). Here we have only one bit so the format can only be '1'. The COMMAND statement defines how the output is to vary with time. Type in these items in a single line as in **Table 1**. The loop can be run any number of times; -1 TIMES means repeat indefinitely. Timings can be in seconds or submultiples greater than nanoseconds.

The output from the generator is fed to a 2-input NAND gate (in the figure, the node number obscures the small circle denoting 'invert'). The Components window has all the default statements ready set, except for MODEL. Select D0_GATE from the list of models on the right. Connect the devices as shown, wiring the two inputs of U2 together so that it operates as an inverter.

With digital simulations we use the Transient Analysis far more than AC or

Table 1

Item	***Interpretation***
0 ns 0	*at time zero (0 nanoseconds) output is level 0*
LABEL = START	*labels a point in the sequence, named START. You could call it anything else, such as LOOP, BEGIN, REPEAT*
50 ns 1	*at 50 ns (from time zero) make the output 1*
100 ns 0	*at 100 ns make the output 0*
200 ns 1	*at 200 ns make the output 1*
210 ns 0	*at 210 ns make the output 0*
240 ns 1	*at 240 ns make the output 1*
260 ns GOTO START	*at 260 ns go to the label start and continue from there*
2 TIMES	*run the loop twice.*

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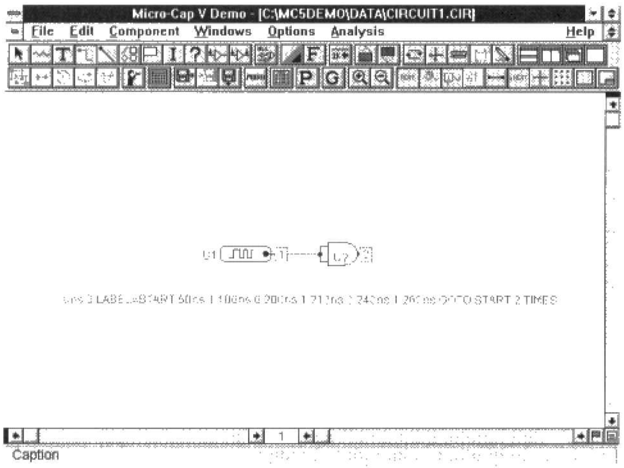


Figure 25. Simple beginnings: one digital signal generator sending a one-bit signal to one logic gate.

26

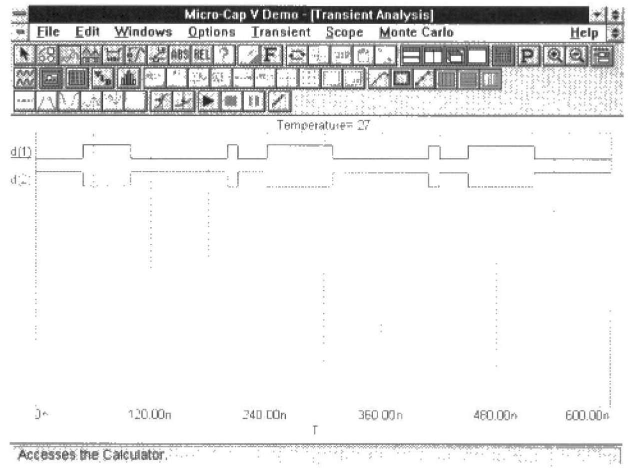


Figure 26. Wavefoms resulting from the action of the setup in Figure 25.

DC. In the Transient Analysis Limits window, set the Time Range to 600 ns, to allow time to go round the loop just over twice. Check the Auto Scale Ranges box. The X Expressions are T, and the Y Expressions are D(1) and D(2) respectively (D for digital). Then Run. The result is **Figure 26**. The upper plot shows the sequence of pulses generated according to the command statement for U1. The lower shows the signal as inverted by the NAND gate.

Try working out other sequences of pulses and plotting them in a Transient Analysis. Instead of 0 and 1 for pulse level, you can use RND or ? for a randomly chosen level, R for a level rising from 0 to 1, F for a level falling from 1 to 0, X for an unknown level, and Z for the high-impedance state.

Table 2

U4	*constant high level to J, K and SET inputs of flip-flops, COMMAND = 0ns 1*
U5	*clock, generating 50ns pulses (10MHz), COMMAND = 0ns 0 LABEL=START 50ns 1 100ns 0, 150ns GOTO start -1 TIMES*
U6	*provides an initial low pulse to reset the flip-flops to 000 output, COMMAND = 0ns 0 5ns 1*

PULSE COUNTER

Now to try something more elaborate. **Figure 27** is a 3-bit counter, built from J-K bistables (flip-flops) (U1-U3). To obtain these, click on Component → Digital Primitives → Edge-Triggered Flip-Flops → JKFF. There is only the Timing Model to select, which is D0_EFF. There are three Stimulus Generators, all with FORMAT = 1 – see **Table 2**.

A Transient Analysis of this network, with Time Range of 1μs (1u), and with Auto Scale Ranges checked, gives **Figure 28**. We have asked for plots of digital levels at nodes 1, 2, 3, 4, 6, and 8. The results are:

- d(1) continuously high, as required
- d(2) shows an initial low resetting pulse, then is continuously high, as required
- d(3) the 10MHz clock
- d(4), d(6) and d(8), considered as a 3-bit binary number

d(4) is the least significant bit incrementing from 000 to 111 repeatedly, as this is a modulo-8 counter. As an alternative, try plotting the output sequence of the inverting outputs of the flip-flops, d(5), d(7) and d(9), and note what sequence of values it produces.

MORE LOGIC

Different states of the counter output can be detected with suitable logic. The simplest state to detect is 000, for which we need a 3-input NOR gate; its output goes high when all three inputs are low. Add such a gate to the network of Fig. 27.

27

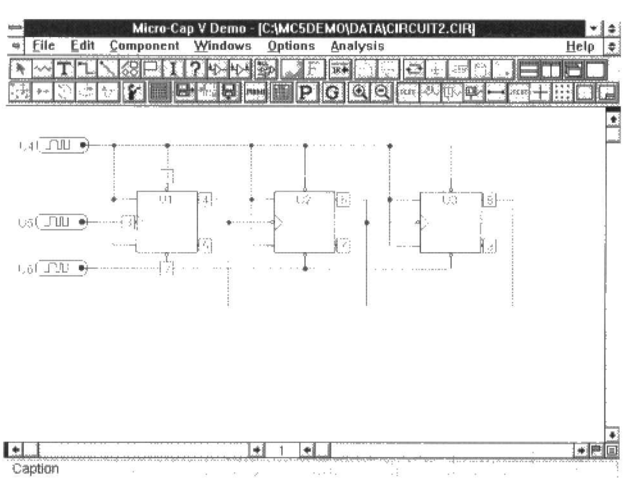


Figure 27. Schematic of a 3-bit counter built from J-K bistables.

28

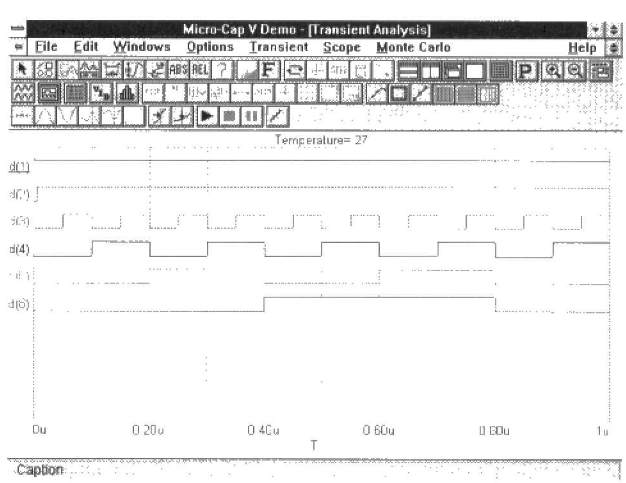
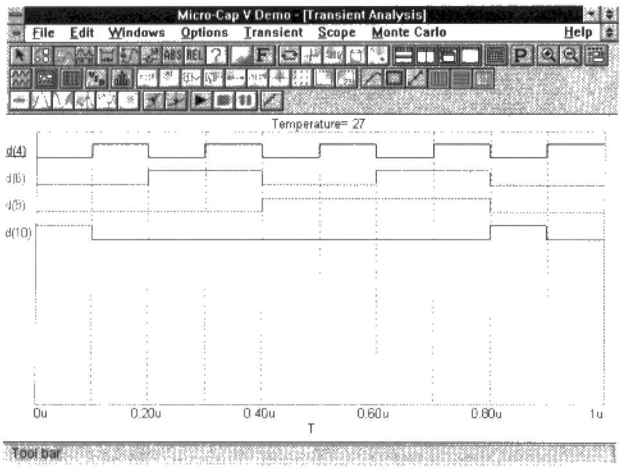


Figure 28. Waveforms resulting from the action of the circuit in Figure 27.

29



30

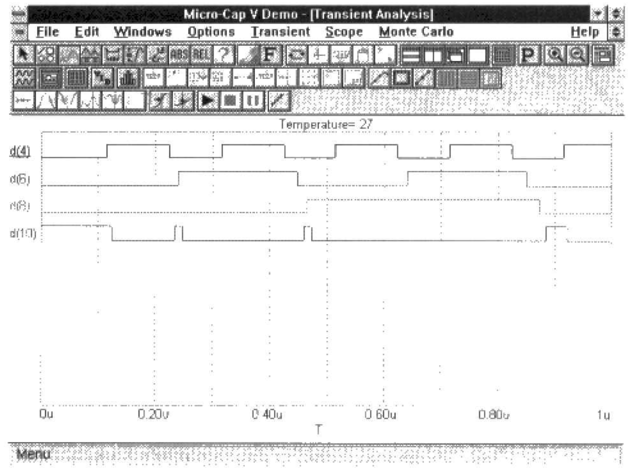


Figure 29. Waveform resulting from adding a 3-input NOR gate to the network in Figure 27.

Figure 30. Waveforms as in Figure 29 but with delay times added to the network.

For its Timing Model, select D0_GATE. Plot its Transient Analysis. As **Figure 29** confirms, the output of the NOR gate d(10) is high whenever the bistable outputs are all low. A network of this type could be used, for example, to flash an LED whenever the count is 000. Typically, the circuit would be operating at a frequency much lower than 10 MHz. The clock rate might be 2 Hz, producing flashes 0.5 s long at each count of 0. Or the clock pulses might be generated irregularly, perhaps by objects passing on a conveyor belt. But in applications in which a high clock rate is required, there is a hazard that needs investigation. This is the effect of delays within the logic elements. We have modelled the circuits with zero delay (D0_EFF and D0_GATE) with the result that Figures 28 and 29 are neatly in accordance with the truth tables. A real bistable or gate does not change state instantly. After the inputs have changed there is a delay before the output changes. For instance, the typical propagation delay of a TTL gate is 11 ns, which is of the same order as the pulses in a 10 MHz network. We can simulate these delays by changing the Timing Models. Use the select arrow to click on each element in turn and edit its Component window. For the flip-flops, change the Timing Model to DLY_EFF. Change the NOR gate model to DLY_TTL. Rerun the analysis (**Figure 30**) and note how, when the output of one counter goes low there is a delay before the output of the next counter changes state. This is why a counter such as this is known as a ripple counter.

Table 3

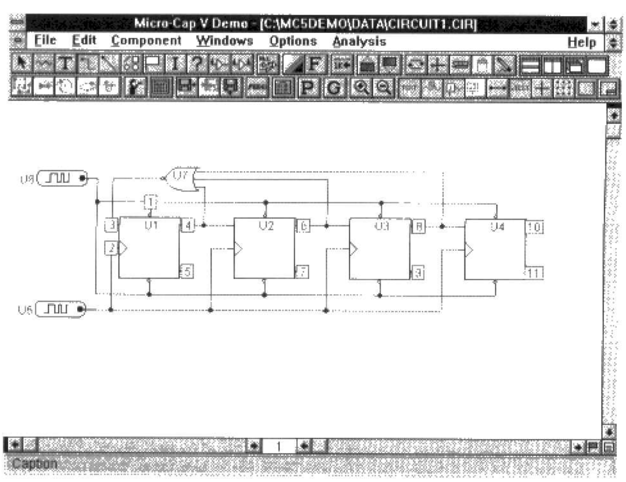
U5	*a 500Hz clock, COMMAND = 0ms 0 LABEL=START 1ms 1 2ms 0 3ms GOTO START -1 TIMES*
U6	*holds set and reset inputs high, COMMAND = 0ms 1*

Note the glitches on the plot of d(10). As the count changes from 001 to 010 [remember, d(4) is the least significant bit], d(5) does not go high until several nanoseconds after d(4) has gone low. There is a transient state in which all outputs are low (000). This is detected by the NOR gate and a short high pulse is generated. The next time this occurs is in the transition from 011 to 100, which actually goes through two transition stages, 010 and 000. The second of these causes another glitch. Eventually the count changes from 111 to 000 (extreme right of plot) and here there are two transition stages, 110 and 100, which delays the start of the high pulse on d(10), making it less than half the length than in Fig 29. It could happen in a counter with more than 3 bits that the delays at each stage would allow d(4) to go high again before the other outputs have all gone low, so there would be no high pulse on d(10) at this stage. The circuit would skip a count. **Figure 30** demonstrates one of the most serious problems in the design of high-speed logic circuits, and emphasises the importance of using circuit simulators. These glitches appear on slow-speed circuits too but, if

Figure 31. Schematic of a so-called walking-ring counter.

Figure 32. Output signals of the walking-ring counter.

31



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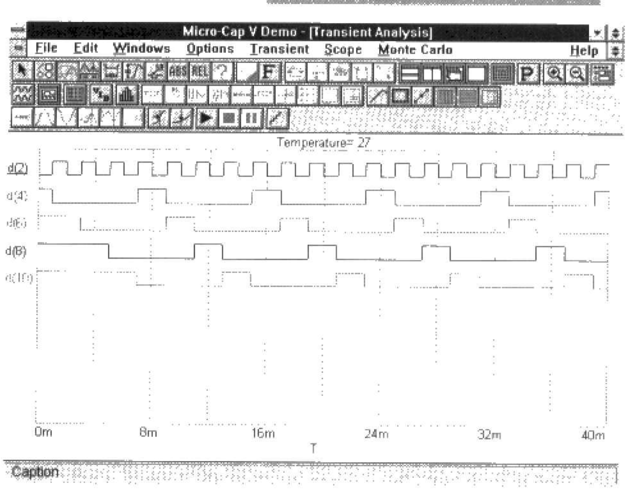

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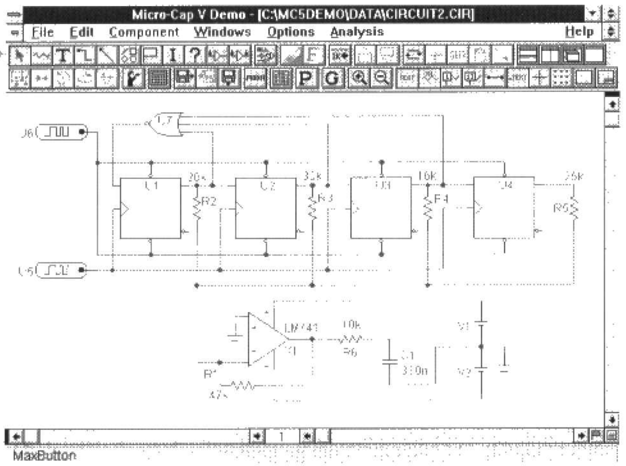

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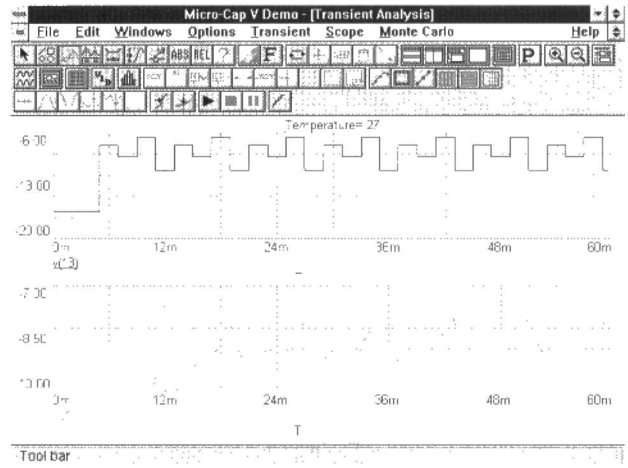


Figure 33. Schematic of Figure 31 modified by weighting the bistables by linking them to a summer.

the circuit is driving an LED or a relay, the glitch is too short to be noticed and it is safe to model the circuit with a no-delay timing model. At high speeds, propagation delays must be taken into account. For high-speed applications, a circuit such as this counter needs to be re-designed, or replaced by a synchronous counter.

MIXED MODE

Some simulators handle only analogue circuits, while others are specialized to simulate only digital circuits. MC5 and several other advanced simulators are able to simulate circuits comprising both analogue and digital sections. This is known as mixed mode simulation. As an example of this, we simulate a digital circuit which generates an analogue waveform. The digital section consists of a walking-ring counter (**Figure 31**), a counter which has a series of outputs which go high one at a time, in a repeating sequence. The counter is built from four D-type bistables. A counter with more stages could produce a more precisely-defined waveform and, as an exercise in digital simulation, the reader can extend the example given here to 8 bits or maybe 12 bits.

Select D0_EFF as the Timing Model for the edge-triggered bistables (DFF). There are two 1-bit Stimulus Generators (Stim1), all with FORMAT = 1 (see **Table 3**).

The 3-input NOR gate, U7, has D0_GATE as its timing model. Test the counter before proceeding. If each bistable is set to begin with, the feedback from the NOR gate causes the output to change in the first three counts from all 1s to a single 1, which then circulates around the counter indefinitely. We could use an initial low pulse to set the counters, but there is another way of doing this. This is to set the Global Parameter DIGINTISTATE to 1. Find this by clicking on Options Global Settings. DIGINTISTATE can be set to 0 or 1, so that all latches or bistables are reset or set to begin with, or to 2 which sets or resets them at random. The result of a 40 ms Transient Analysis is shown in Fig. 32 in which d(2) is the clock. All outputs are high to start with, but they go low in turn until only one output is high at any one instant, as expected in a ring counter. This completes the digital section of the circuit.

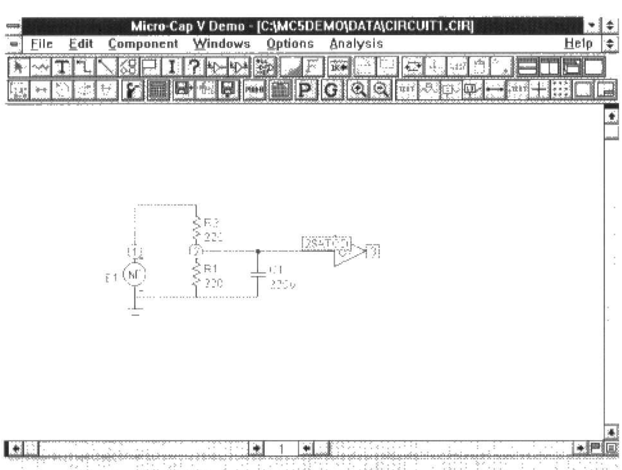
Figure 34. Waveform resulting from a 60 ms Transient Analysis of the output of the op amp in Figure 33.

The next step is to use these outputs to feed currents of different values to the input of an op amp summer. In **Figure 33** the outputs from the bistables are weighted by connecting them to the summer through resistors of different values. We have used LM741 as the op amp model, but almost any other one will do. V1 and V2 are set to 18 V each to power the op amp. Figure 33 is displayed without node numbers to allow the connections to be clearly seen. If node numbers are enabled, we find that the nodes at which the digital section connects to the analogue section have had digital-to-analogue converters added to them. These are not converters in the usual sense (though it is possible to simulate various kinds of converters when required) but are interfaces between the two sections,

Figure 35. Use of a potential divider to reduce a signal which is smoothed at the same time by a capacitor.

Figure 36. This digital signal is not satisfactory because its transitions are not clearly defined.

35



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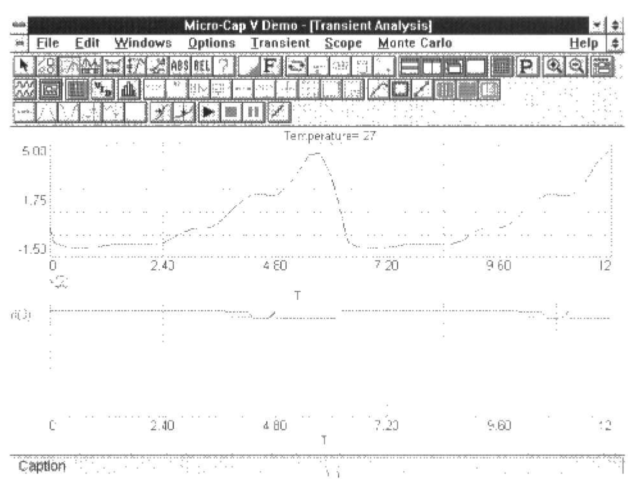
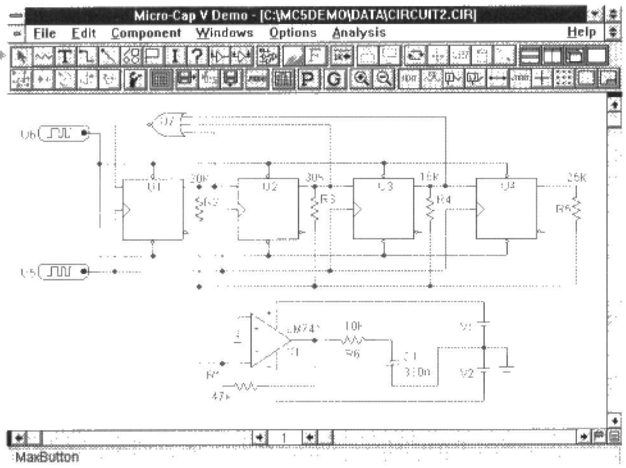




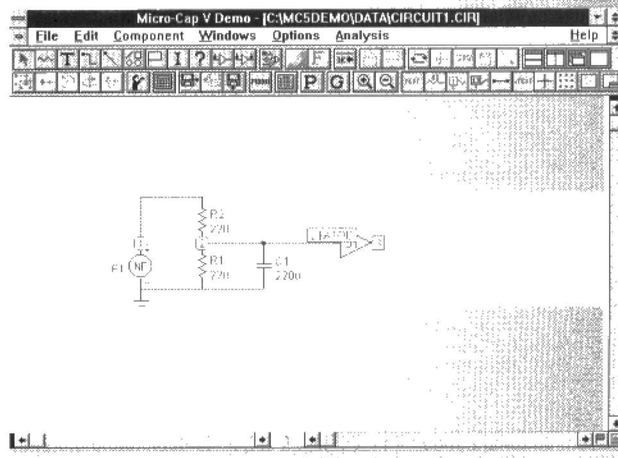


Figure 37. The signal in Figure 36 is improved by inserting a comparator between the source and potential divider.

automatically placed there for the benefit of MC5 in performing its analyses.

Figure 34 shows a 60 ms Transient Analysis of the output from the op amp V(13). This has a stepped form as each output from the counter goes high in turn. Although this is an analogue waveform, it reveals its digital origin. The signal is passed through a low-pass filter to node 16, where it has the appearance of a modified triangular wave. When plotting these curves we selected Auto Scale Ranges for the first few trial runs. The curve for V(13) fitted neatly in the automatically selected ranges (0.06, 0 and –6, –20). But the curve for V(12) begins with very low values when most of the outputs are '1', which means that the interesting part of the curve is plotted with too small an amplitude to show the waveform clearly. So we deselect Auto Scale Ranges. We leave the ranges unchanged for V(13) but edit those for V(12) to 0.06, 0 and –7, –10.

This circuit is a simplified version of a function generator IC. By increasing the number of stages and by choosing resistor values carefully, it is possible to approximate to many kinds of waveform, including sine waves. Here is a field for experimentation by the reader.

MORE MIXED MODE

In this circuit we pass a signal in the reverse direction, from an analogue circuit to a digital circuit. This is also a chance to look at the formula-type voltage source, or NFV, which is one of MC5s Function Sources. When this is placed, the Component window asks for its VALUE, which is a formula expressing the output voltage in terms of other voltages or currents and of time. In this example, enter:

VALUE = 3*PI – 6*sin(t)
– 3*sin(2*t) - 2*sin(3*t)
– 1.5*sin(4*t)

where PI is π, equal to 3.1416 and * signifies multiplication. If you have read about Fourier series you may recognise that these are the first 5 terms of the series which defines a saw-tooth waveform. The amplitude of this waveform is just over 9 V and its frequency is 0.159 Hz. If you try to connect the NFV directly to a logic gate, you will get a 'Digital Warning' from MC5 that the voltage is too high, assuming that the logic operates on 5 V. Use a potential divider to reduce this (**Figure 35**), add a capacitor to smooth the waveform, and feed the signal to a digital inverter gate. MC5 automatically puts an A-to-D converter in place. The Transient Analysis (12 s, 501 points) shows the voltage waveform at node 2 and the digital output at node 3 (remember that this is for MC5's use and does not form part of a real circuit). The digital output (**Figure 36**) is unsatisfactory because, although it is low when V(2) is high, and high when V(2) is low, as might be expected from an inverter, there are occasions when V(2) is slowly changing between high and low and the output of the inverter is indeterminate. At 4.8 s when there is a small local fall in V(2), there is a momentary high spike on the output.

This is a common problem when analogue and digital circuits are connected. To improve the interface between them we must make sure that V(2) never lingers around the threshold input level of the inverter. One way to do this is to insert an op amp, wired as a comparator between the source and the potential divider (**Figure 37**). The battery V3 provides a reference level, or this could be provided by a voltage reference or a variable potential divider in a real circuit. The plot (**Figure 38**) shows the original waveform, and that of the op amp output, after being reduced by the potential divider (multiplied by 4 in the display to make its shape easier to see). Note that although it is a squarish wave, it is still an analogue one. Its transitions are so much sharper than those of the original waveform that the output of the inverter d(4) now switches between high and low with only a very short indeterminate state, just about discernible as a thickening of the trace on the changes of state.

Figure 38. Waveforms of the original signal, that of the op amp, and the resulting digital signal which is now clearly defined.

Once you can get an analogue circuit to change the state of a logic gate, you can get it to do almost anything. As an MC5 exercise, build logical circuits on to the inverter gate to, for example, trigger a bistable or a counter. You could add another interface between the analogue and logical sides to trigger the bistable to reset as the analogue voltage falls below a given level. Or use the output from the inverter to enable or disable a pulse train from a Stimulus generator. Such a circuit could be used to flash an LED when the analogue level exceeds a given value, and could be the basis of a frost warning or over-heating device.

ANSWERS TO INVESTIGATION (3)

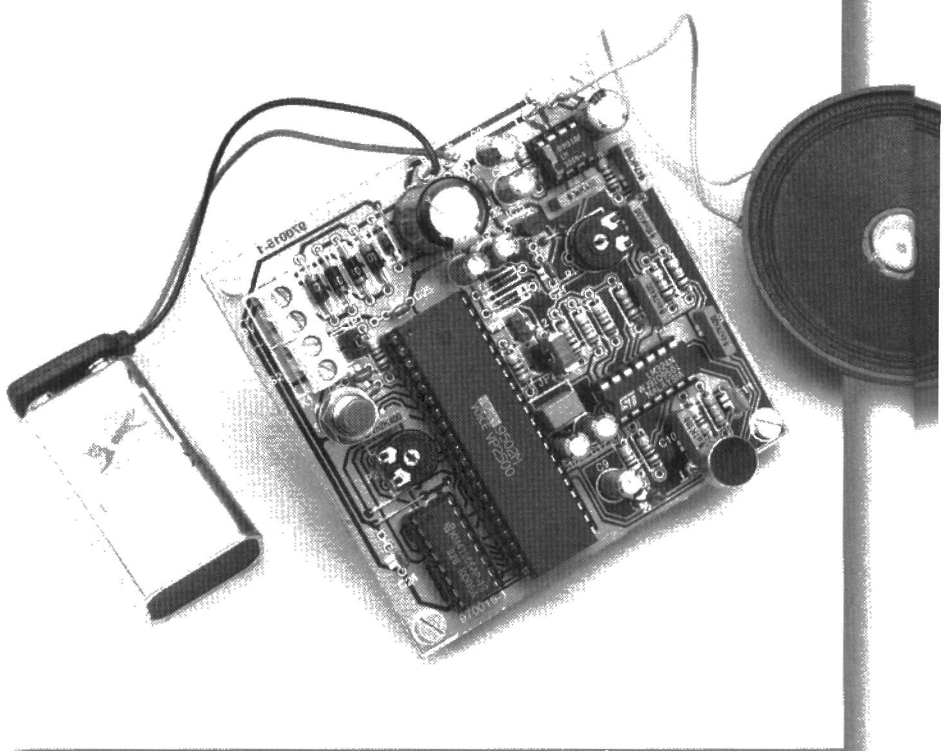
The filter presented for investigation last month is first examined by an AC analysis, with the frequency range from 100 Hz to 1 MHz. This shows a clear peak at 123 kHz. Closer examination over the range 100 kHz to 150 kHz gives f_c = 123.500 kHz. On the same graph we find the –3dB points at 120.960 kHz and 126.127 kHz, a bandwidth of 5.167 kHz – a narrow-band filter. A Transient analysis with the frequency of V1 set to 123.5 kHz shows that amplitude comes to a steady value after about 80 μs and, given input amplitude 0.1 V, the output amplitude is 0.21 V, a gain of 2.1.

[960102-4]

talking doorbell

digitize your welcome message

We recently came across an interesting IC which makes digital recording and playback of short messages and other sounds easier than we ever thought possible, and cheaper, too! The talking doorbell described here is a project which is fun to build and use for beginners and more experienced constructors alike.



main specifications

Sampling frequency:	*adjustable, 12.8 to 64 kSamples/s*
Message length:	*4 to 20 seconds*
Playback frequency band:	*300 Hz to 3.4 kHz (−30 dB)*
Memory:	*single DRAM, 64 or 256 kBit*
Output power:	*0.5 W Max.*

Design by H. Bonekamp

If you've always wanted to greet your visitors with a personalized message when they ring your doorbell, here's your chance to fulfill that wish. Be it your own voice, a barking dog, a train sound or a short piece of music, it is easily stored and played back at quite reasonable quality by the present circuit. The length of the message or sound you wish the circuit to reproduce is dependent on the quality, as will be shown further on.

How it works

The circuit diagram of the Talking Doorbell shown in **Figure 1** follows a suggested application circuit as published by the manufacturer of the voice recorder/playback IC, the VP-2500 from Eletech (IC3). Let's examine the circuit in some detail to understand its structure and how it was designed.

The signal picked up by electret condenser microphone X1 is amplified more than 100 times by opamp IC2b. A low-frequency roll-off of about 300 Hz is created by R7 and C10. Two other components, R8 and C11, set a high frequency roll-off point of about 600 Hz. Although that may seem an extremely low value, speech reproduction is still quite acceptable. The reason for using such a low roll-off frequency is that it optimizes the drive margin of the sigma-delta modulator. The filtered speech signal is then applied to a comparator, IC2d, which turns its analogue input signal into a stream of logic ones and zeroes which is applied to the COMPDATA input of the voice recorder/playback chip.

According to Eletech, the VP-2500 has an internal circuit which applies Continuously Variable Slope Delta (CVSD) modulation. CVSD uses only one bit of storage per sample clock (to represent waveform direction, i.e. 'up' or 'down'), as opposed to 8 bits or more per sample for, say ADPCM (Analogue/Digital Pulse Coded Modulation). That explains why CVSD sampling rates are much higher than those of ADPCM. Also, while ADPCM sampling rates are usually fixed and tied to certain compression ratios (like 2:1 or higher), CVSD allows (in theory) any compression rate to be implemented

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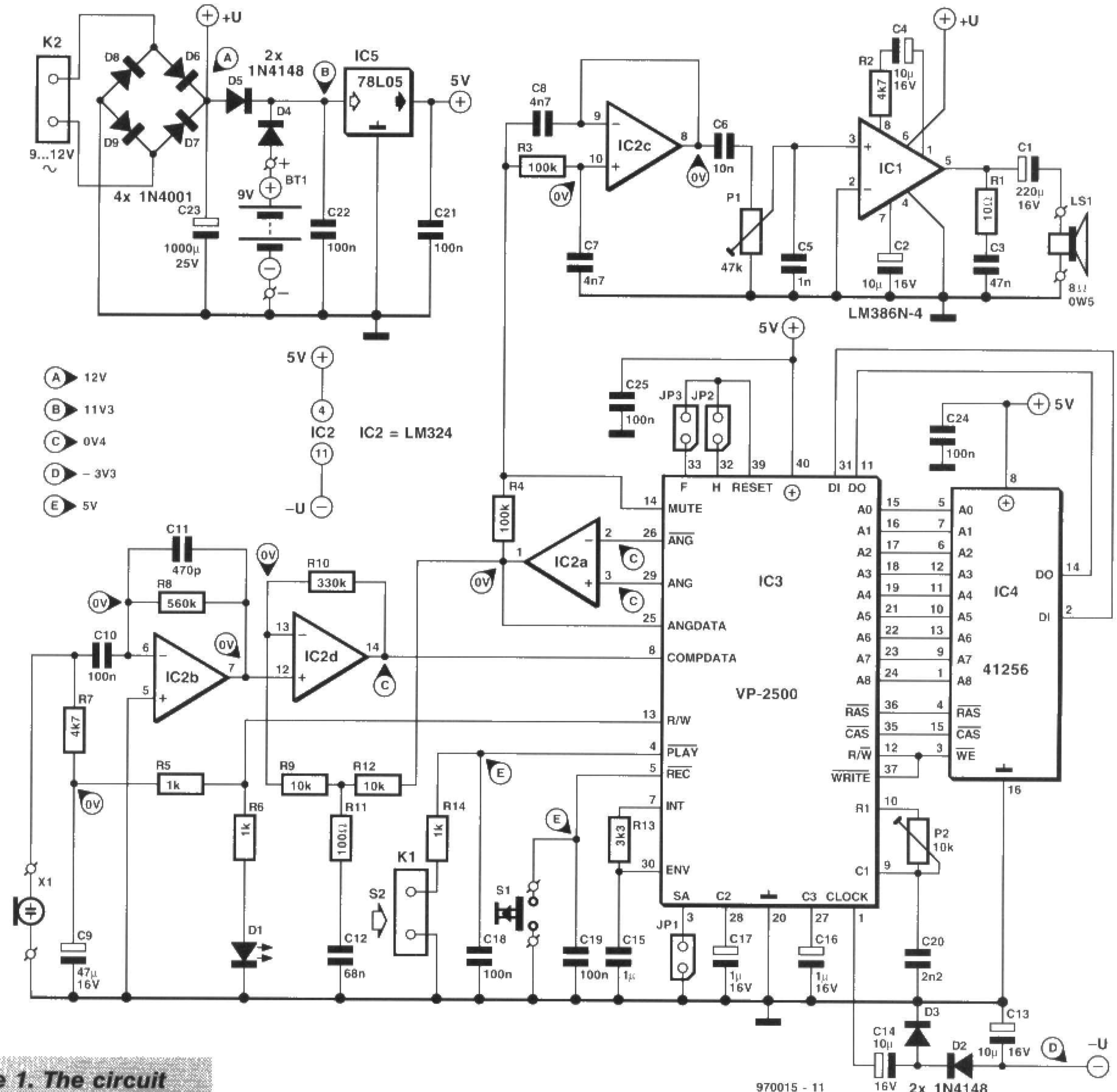

Figure 1. The circuit diagram of the Talking Doorbell largely follows the suggestions made by Eletech, the manufacturer of the VP-2500 chip.

simply by changing the sampling rate.

In the present circuit, the sampling rate is adjusted with a preset, P2, to any value between about 12,800 and 64,000 samples/s. The lowest rate allows a message length of about 20 seconds, the highest, one of about 4 seconds. Speech reproduction quality is, obviously, proportional with the sampling rate applied while recording the message.

The VP-2500 has a companion DRAM (dynamic RAM) type 41256 or 4164 which is used to store the digitized message. The advantage of a DRAM is mainly its low cost. On the down side, a DRAM has to be refreshed, and it is basically a volatile memory component which loses its contents when the power is switched off. Fortunately, both disadvantages are far from problematic here because (1) the VP-2500 handles all the refreshing and (2) a back-up battery may be used to uphold the supply voltage when the mains power is gone for some reason. The DRAM size (64 or 256 kbits) is selected with a jumper, JP1.

Recording is initiated by briefly pressing push-button S1. The memory is full when LED D1 goes out.

Playing back the message is equally simple: all you (or your visitor) has to do is press the doorbell switch connected to terminal block K1.

The recorded message is played back (how come we keep using terms associated with tape recorders?) from the DRAM, through the demodulator contained in the VP-2500, a digital-to analogue converter (IC2a), a second-order low-pass filter set up around IC2c (roll-off at about 200 Hz to remove the sampling frequency component), a run-of-the-mill power amplifier based on the LM386, and, finally, a miniature loudspeaker. The output power is about 0.5 W, which will be sufficient for most practical applications.

The circuit is normally powered by the bell transformer which is connected to K2. The 5-V supply is traditional and based on a three-pin voltage regulator, IC5. D4, D5 and battery Bt1 form an (optional) back-up supply which prevents the programmed data in the DRAM being lost when the mains voltage disappears (briefly). If a direct voltage is connected to K2, the voltage should be around 12 V. If not, the back-up battery may discharge across this supply. Current consumption of the circuit is less than 300 mA. Current drain on the back-up battery is less than 15 mA. Obviously, with an ordinary 9-V battery connected, the power outage should not last too long. A 450-mAh alkaline battery, however, will last about 30 hours.

The function of the jumpers in the circuit is as follows.

- Jumper JP1 fitted: selects 256 kBit DRAM (41256);
- Jumper JP1 not fitted: selects 64 kBit DRAM (4164);
- Jumper JP2 fitted: play message once;
- Jumper JP3 fitted: play message twice.

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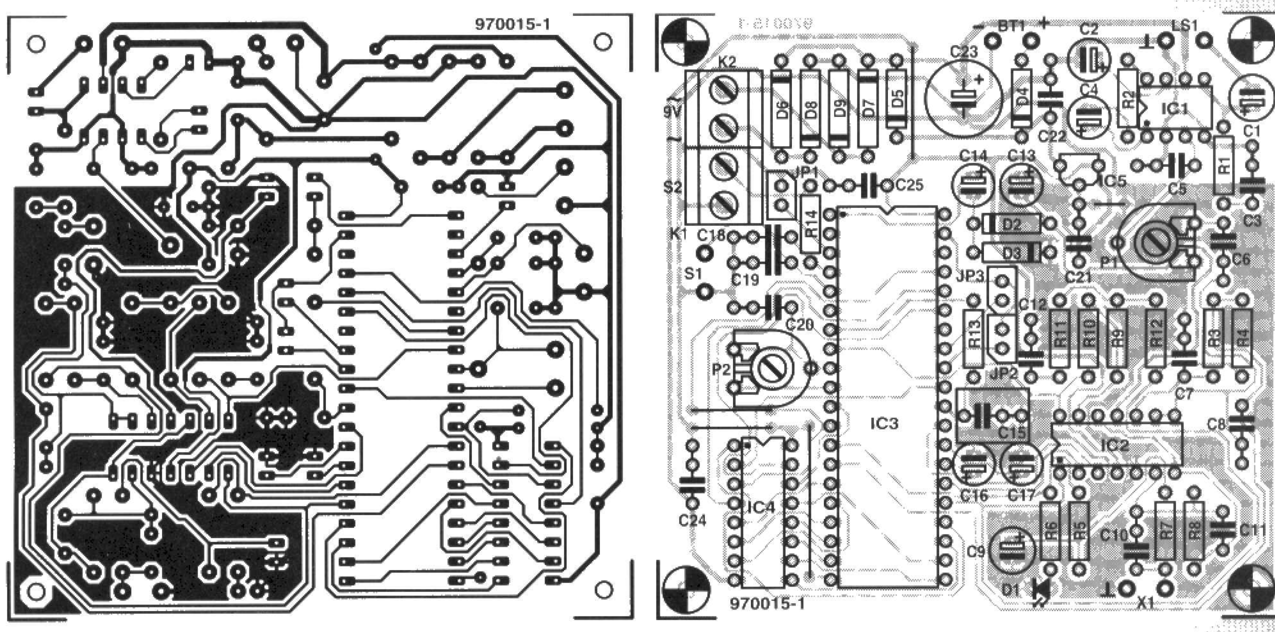

COMPONENTS LIST

Resistors:
R1 = 10Ω
R2,R7 = 4kΩ7
R3,R4 = 100kΩ
R5,R6,R14 = 1kΩ
R8 = 560kΩ
R10 = 330kΩ
R11 = 100Ω
R13 = 3kΩ3
R9,R12 = 10kΩ
P1 = 47kΩ preset H
P2 = 10kΩ preset H

Capacitors:
C1 = 220µF 16V radial
C2,C4,C13,C14 = 10µF 16V radial
C3 = 47nF MKT
C5 = 1nF MKT
C6 = 10nF MKT
C7,C8 = 4nF7 MKT
C9 = 47µF 16V radial
C10, = 100nF MKT
C18,C19,C21,C22,C24,C25 = 100nF Sibatit
C11 = 470pF
C12 = 68nF MKT
C15 = 1µF MKT
C16,C17 = 1µF 16 V radial
C20 = 2nF2 MKT
C23 = 1000µF 25V radial

Semiconductors:
D1 = LED, red, high-efficiency
D2...D5 = 1N4148
D6...D9 = 1N4001
IC1 = LM386N-4
IC2 = LM324
IC3 = VP-2500 (Eletech)
IC4 = 41256 or 4164 DRAM (see text)
IC5 = 78L05

Miscellaneous:
LS1 = 8Ω 0.5W loudspeaker
X1 = electret microphone, e.g., type CM 105-8
K1,K2 = 2-way PCB terminal block, pitch 5mm
S1 = push-button
JP1,JP2,JP3 = 2-pin header with jumper
BT1 = 9-V battery (optional)

CONSTRUCTION

The circuit is pretty easy to build on the printed circuit board whose artwork is shown in **Figure 2**. There are no special points to note except, perhaps, that it is best to start with the five wire links ob the board, so that these are not forgotten later. It is recommended to use sockets for all ICs. The finished and tested board (prototype) is shown in the introductory photograph.

To help you connect the circuit to its external components, and locate the main settings and jumpers, a wiring diagram is given in **Figure 3**.

(970015)

Source: Eletech databook, QuikVoice™ LSI Voice Components

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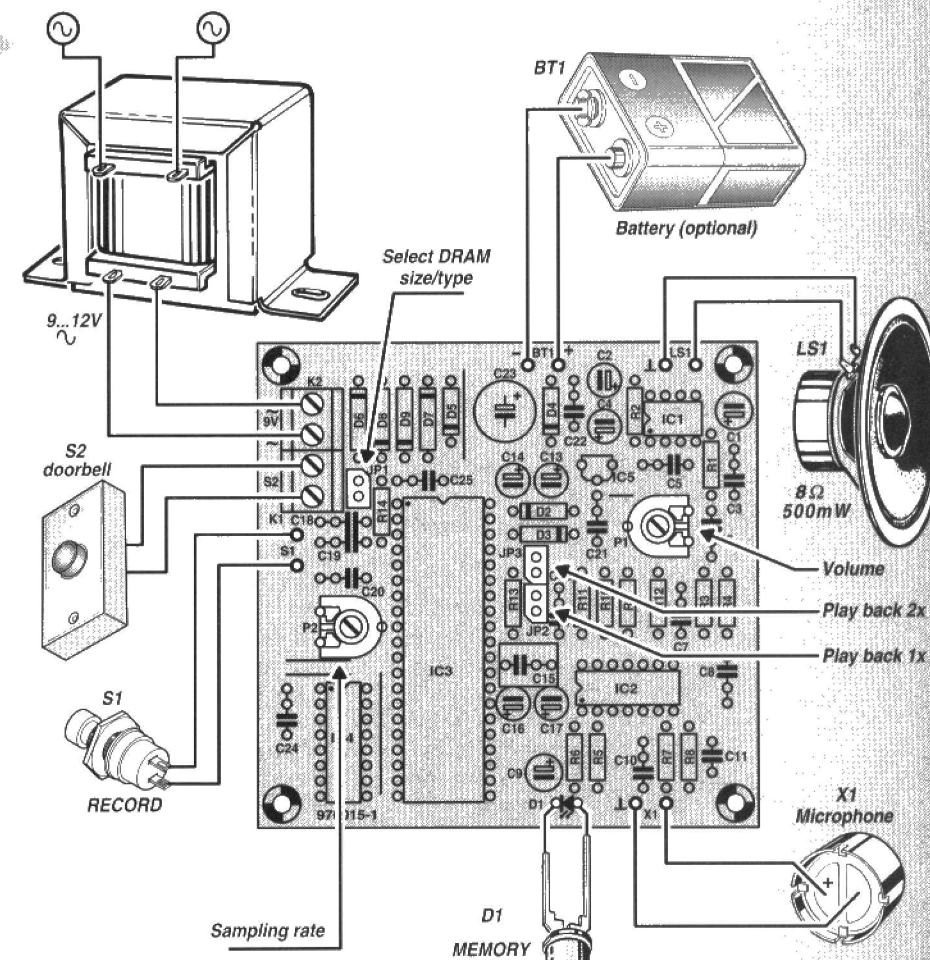
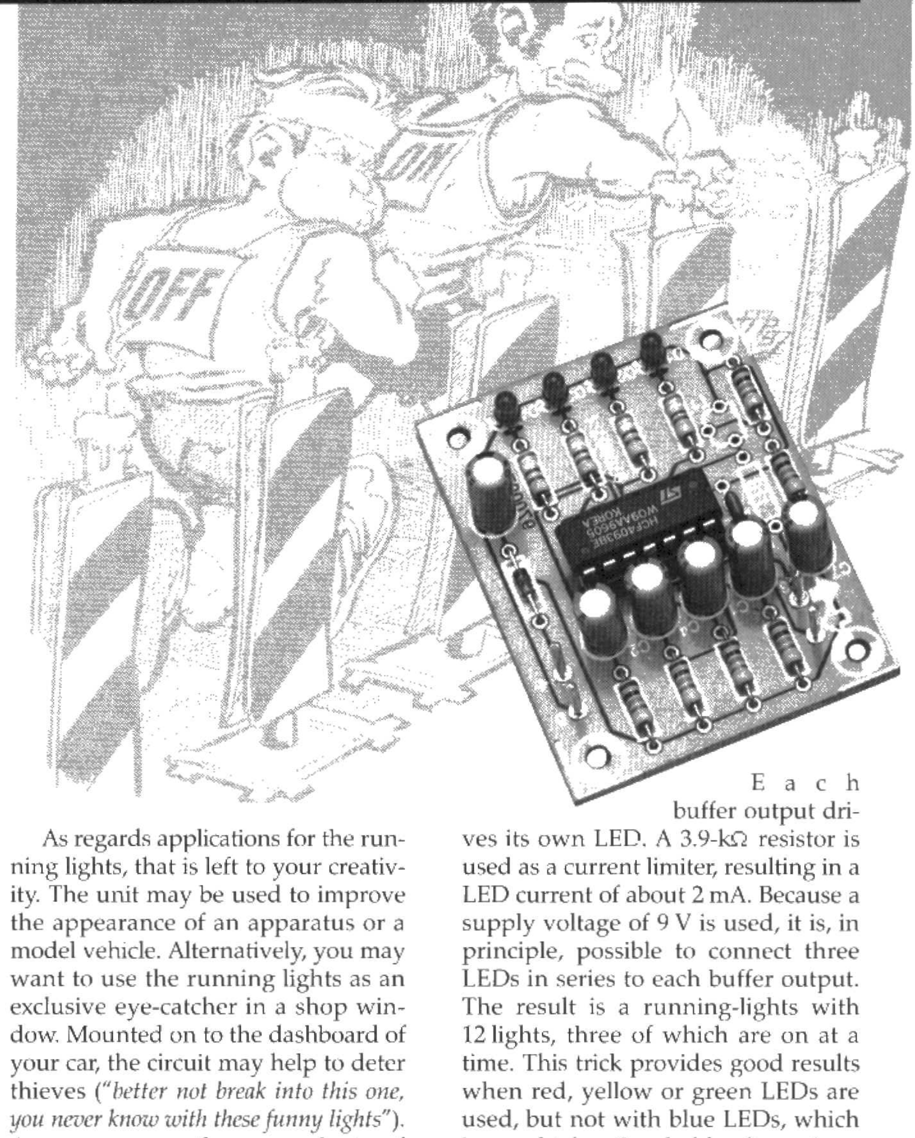


mini LED running-lights

imitating the flexible tubelight

Flexible tubelight units containing many vividly coloured lights are very popular ornaments these days, and they are seen in many shop windows, bars and discotheques. Although extremely compact, the circuit presented in this article contains all the electronics needed to make such a 'lighting tube' yourself. Thanks to the modular structure of the circuit, the number of lights may be extended to any requirement. Because LEDs (light emitting diodes) are used instead of small lamps, different colour patterns are easily created.



Running lights are second to none eye-catchers, giving a visual impression of an infinite series of light points marching (in single file) to an unknown destination. In reality, the case is, of course, much simpler: the lights do not 'leave' the end of the tube, and they do not, by any means, form an endless series. In fact, only a number of lamps light at the same time. The basic version of the miniature running lights presented in this article contains four light points in the form of small LEDs. If you want more lights, all you have to do is cascade more modules, or add LEDs.

Design by L. Lemmens

As regards applications for the running lights, that is left to your creativity. The unit may be used to improve the appearance of an apparatus or a model vehicle. Alternatively, you may want to use the running lights as an exclusive eye-catcher in a shop window. Mounted on to the dashboard of your car, the circuit may help to deter thieves (*"better not break into this one, you never know with these funny lights"*). As you can see, there are plenty of possibilities for this circuit.

One IC does it all

The circuit diagram shown in **Figure 1** proves that the circuit is a straightforward design. The timing elements in the circuit are four identical RC combinations of 100 kΩ and 10 µF. In practice, this combination provides a delay of about one second. We also know from experience that the exact trigger levels of the buffers used differ slightly between manufacturers of the type 4093 IC. The differences may result in a spread of 10 to 20 per cent in the delay time. If an SGS-Thomson 4093 is used, for instance, the delay per circuit is of the order of 0.8 seconds.

Each buffer output drives its own LED. A 3.9-kΩ resistor is used as a current limiter, resulting in a LED current of about 2 mA. Because a supply voltage of 9 V is used, it is, in principle, possible to connect three LEDs in series to each buffer output. The result is a running-lights with 12 lights, three of which are on at a time. This trick provides good results when red, yellow or green LEDs are used, but not with blue LEDs, which have a higher threshold voltage. Anyway, blue LEDs are very pricey, so don't even bother to ask your electronics retailer for, say, 12 pieces!

The combination C7, R9, R10, R11 and T1 provides a power-on reset function for the running lights. Transistor T1 starts to conduct immediately after the power supply is switched on, keeping pin 2 of IC1a logic low for the moment. Consequently, the output of the gate is logic high. LED D1 will light during the reset period. At the same time, the logic state of the other three gates is not determined yet. However, after a short delay, any LED(s) which may light will go out as a result of the high level at the output of IC1a. After the reset period (which lasts a few seconds), the collector voltage of T1

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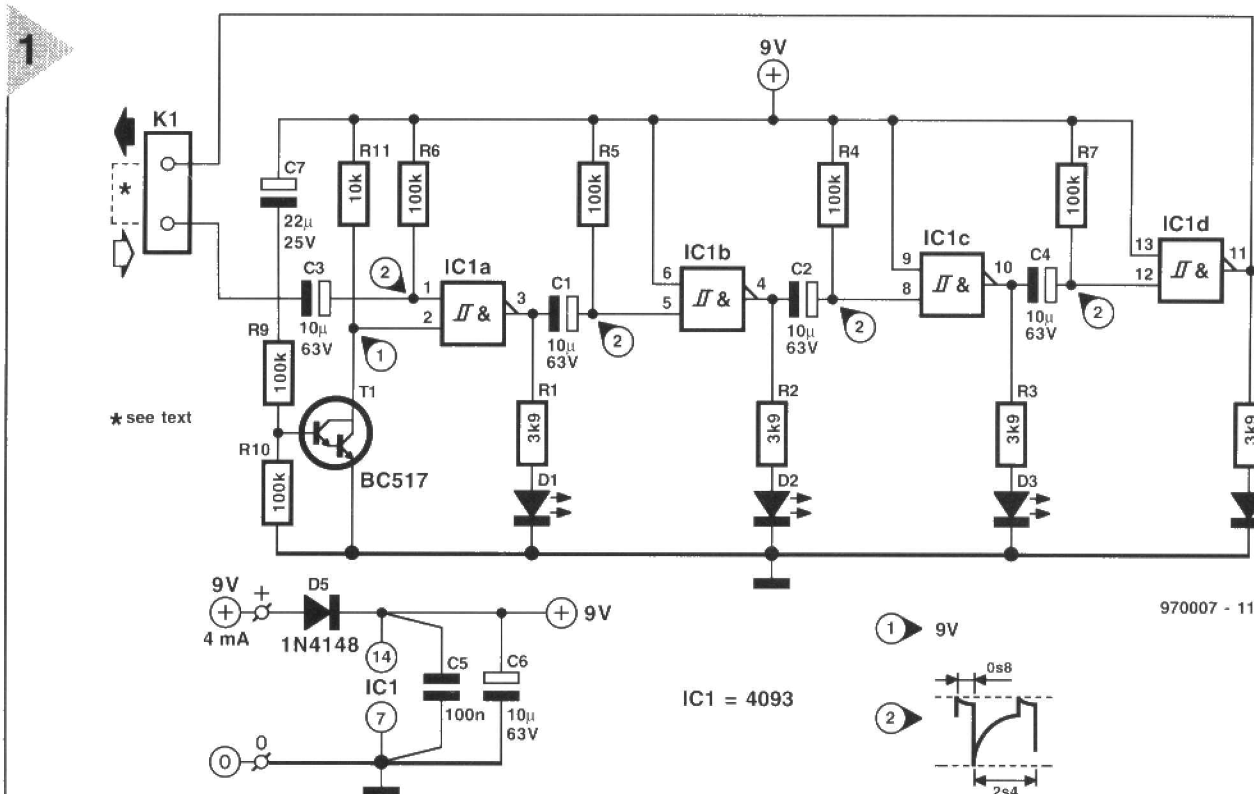

Figure 1. Circuit diagram of the miniature running-lights. The circuit is also suitable as a burglar deterrent for use in cars.

becomes high. The output of IC1a, pin 3, then drops low as a result of the high level at the gate inputs, pins 1 and 2. LED D1 goes out. The high-to-low level transition at the output of IC1a results in a logic low level at pin 5 of IC1b during the previously mentioned RC time. The result: a logic high gate output, and LED D2 lights. When the RC time has elapsed, the gate output goes low again, LED D2 goes out, and gate IC1c is triggered next. This chain reaction is 'self-supporting' because the output of IC1d is connected to an input of IC1a, via K1.

The principle of operation is illustrated in the timing diagram shown in **Figure 2**. The drawings clearly show that each 1-to-0 transition at the input of a NAND gate configured as an inverter causes a negative pulse at the input of the next buffer.

The entire circuit may be powered from a regular 9-V battery, the current consumption being just 4 mA. For security's sake, a supply reversal protection is provided in the form of diode D5.

A function which has not been discussed so far is that of connector K1. On the printed circuit board, this connector appears in the form of two solder pins. As already mentioned, it is possible to connect several modules to form a chain (or cascade). If you use just one module, the output signal of IC1d is fed back to the input of IC1a. That is simply done by interconnecting the two pins of K1 (i.e., the input and the output arrow). If two modules are connected in series, the output of the first module is connected to the input of the next one. The output of the second module is then connected back to the input of the first one. In this way, the circuit is closed, and the running lights extended by one module. **Figure 3** shows how the modules as described here may be cascaded.

Construction

A ready-made printed circuit board is unfortunately not available through our Readers Services. The copper track layout and component mounting plan are shown in **Figure 4**. Start by fitting the two wire links on the board, so that these are not forgotten later. Then it's time to mount the passive parts. Mind the polarity when fitting the electrolytic capacitors and the diode (D5). After fitting T1 and IC1 (the latter preferably in an IC socket), all you have to do is mount the solder pins and the four LEDs. If the luminous row is mounted on to a front panel or into a plastic tube, the connections between the LEDs and the board are best made using light-duty flexible wire.

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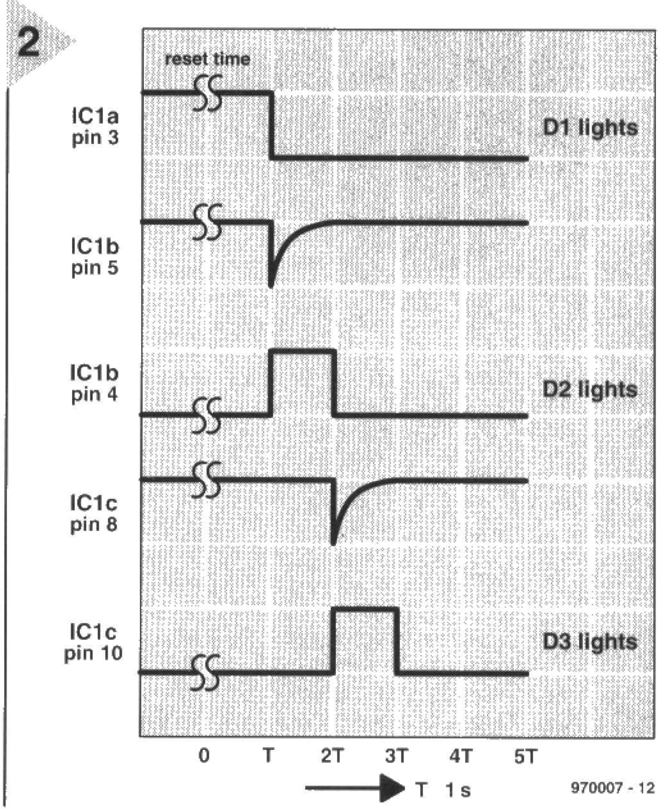
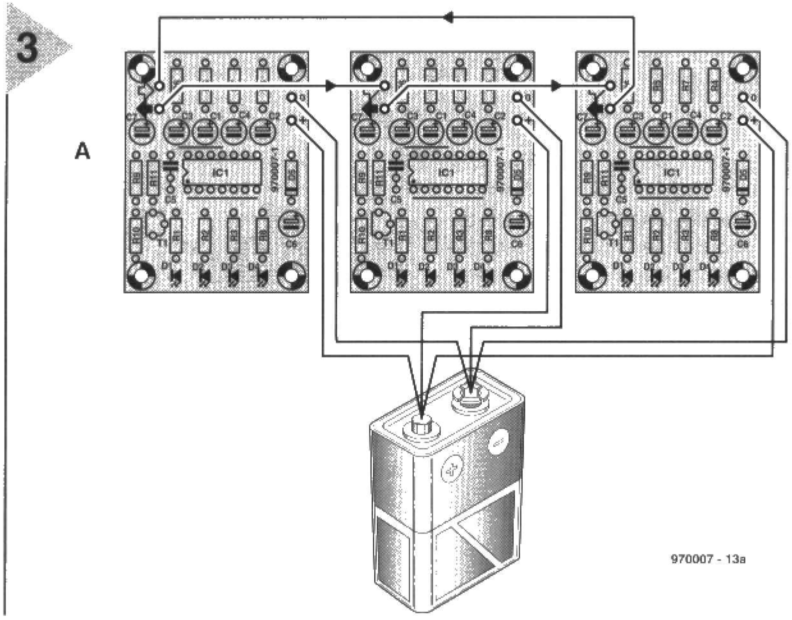


Figure 2. This diagram shows how the buffers actuate one another in 'ripple' fashion. Because the output of the last buffer is connected back to the input of the first, the running-lights will loop forever.



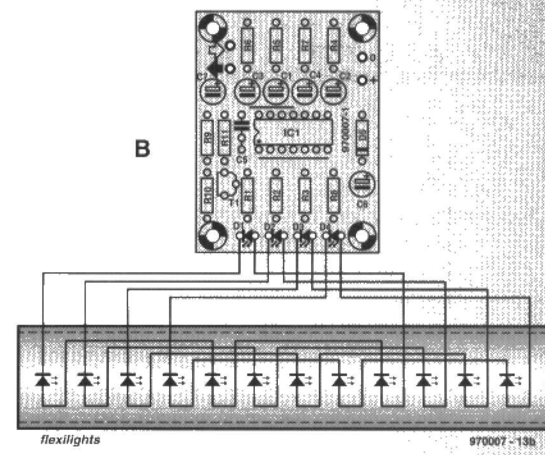


Figure 3. Multiple modules may be connected in series without problems. Diagram A shows how this is done in practice. Diagram B illustrates how a small 'snakelights' unit may be built using just one module.

Having finished the construction, you are well advised to check the board and all connections for short-circuits. If everything seems to be in order, it is time to connect a 9-volt (PP3) battery. As soon as the supply voltage is present, at least D1 will light. In case more LEDs are on, these will go out fairly quickly. After the reset time (which is long enough for one module using the component values shown), the LED will appear to start walking. The project works!

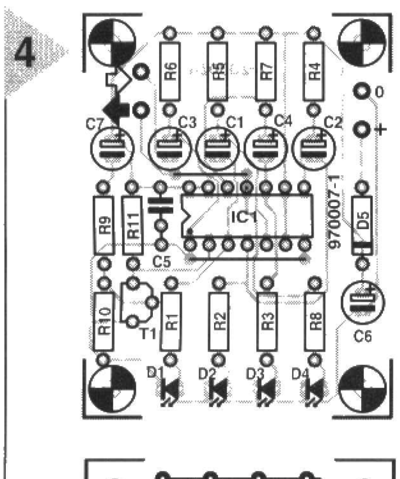


Figure 4. Copper track layout and component mounting plan of the printed circuit board designed for the mini running-lights (board available read-made, see Readers Services page).

Cascading modules

As already mentioned, several modules may be connected in series (cascaded) without problems. Because a central reset is used, the reset circuit may be omitted from the extra modules. In other words, resistors R9 and R10, capacitor C7 and transistor T1 are not fitted on any of the additional modules. The central reset time has to be adapted, however, depending on the number of extra modules. The right time is about 5 seconds per module. For example, if two modules are used, the required delay is 10 seconds. With three modules, the reset time is 15 seconds (minimum). Capacitor C7 normally has a value of 22 µF, and has to be increased to 100 µF if a maximum of five modules are used. In practice, this capacitor value will ensure sufficient time to switch the circuit to the proper starting condition, which is reached when only D1 lights. By increasing the value of C7 to 1,000 µF you will notice that very long reset times may be achieved, in this case, approximately 5 minutes.

After adapting the reset time to the number of modules used, the circuit is ready for use, and may be fitted into an enclosure. As mentioned before, there are plenty of applications.

COMPONENTS LIST

Resistors:
R1,R2,R3,R8 = 3kΩ9
R4-R7,R9,R10 = 100kΩ
R11 = 10kΩ

Capacitors:
C1-C4 = 10µF 63V radial
C5 = 100nF
C7 = 22µF 25V radial

Semiconductors:
D1-D4 = LED, 2mA
D5 = 1N4148
T1 = BC517
IC1 = 4093

Miscellaneous:
K1 = 2 solder pins

Help, it doesn't work!

In case the circuit does not work spot-on, finding the error will not be too difficult. After connecting the supply voltage, pin 2 of IC1a should be logic low initially. After a few seconds, this level changes to 'high'. If not, C7 is connected the wrong way around, or T1 is defective. If a high level is present on both inputs of the buffer, the output is always low, whereupon the relevant LED goes out. If the same input level condition results in a 'high' level at the gate output, then the IC is defective. If the gate output is logic high, but the LED remains out, the LED is probably fitted the wrong way around. Finally, if the battery is properly connected, but there is no voltage on the circuit, D5 is probably defective or fitted the wrong way around. That's about all that can go wrong with this circuit. (970007)

SWITCHBOARD

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WANTED. Late Labcenter PCB drawing, software with manuals. Please phone Mark on 0181 761 7259.

FOR SALE. Surplus electronic components. Send SAE for list to Alan Auden, 187 Whitton Dene, Isleworth, Middlesex, England, TW7 7NJ.

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ELEKTOR ELECTRONICS 2/97

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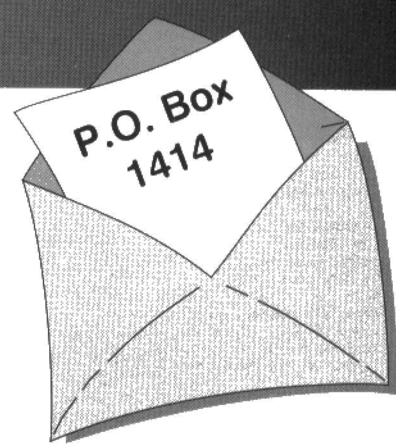
LETTERS



UHF Modulator

In the article 'Video Test Generator' on page 27, *Elektor Electronics* October 1996, a UHF modulator is mentioned. Could you provide me with the manufacturer's name and address, please.

M. Hewitt

This modulator is manufactured by Hwa Lin. Co. Ltd., marketed by Conrad, and obtainable as a one-off component via our advertiser C-I Electronics, P.O. Box 5544, NL-3008-AM Rotterdam, The Netherlands, fax (+31) 10 4861592, email dil@euronet.nl.

Which LED?

Many Elektor circuits seem to use LEDs described as 'high-efficiency' or low-current' types. Unfortunately, I do not quite understand why high-efficiency LEDs are sometimes used in current source circuits. Also, I often come across LEDs identified as 'high brightness', high intensity' or 'high luminosity' types. Can you enlighten me on this?

N. Finn

LEDs come in an amazing variety these days, and there is, indeed, some confusion about their proper descriptions. Leaving the many different LED shapes and sizes for what they are, even a small group like red LEDs has a diversification of four or five sub-types. With Temic, one of the largest manufacturers of LEDs, these are, for example:

1. *Universal: dark red with fair brightness*
2. *High Efficiency: slightly lighter red, high efficiency, average brightness, also available in soft orange, yellow, yellow-green and bright green.*
3. *High Intensity: high brightness even at low currents, high efficiency, available in dark red, yellow and soft orange*
4. *Low Current: a high-efficiency LED specially designed for low currents, available in red, yellow and green; small current capacity: I_{fmax} = typ. 7 mA!*

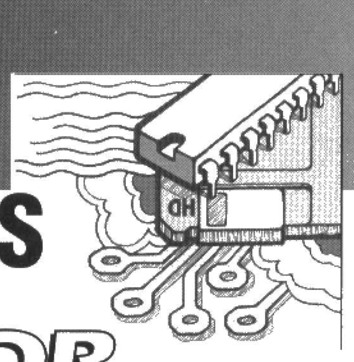
An overview of the 'on' voltage for a number of Temic LEDs at currents of 2, 10 and 20 mA are shown in the table.

In current sources, the LEDs you mention should produce a voltage drop of 1.6 to 1.7 V at 2 mA. According to the table, that may be achieved by using a red high-efficiency or high-intensity LED. In case of doubt, simply measure the voltage across the LED and, if necessary, replace it with a type that does provide the correct voltage drop.

LED Type	2mA	10mA	20mA
Universal (R)	1.55V	1.6V	1.65V
High Efficiency (R)	1.7V	1.8V	2V
High Intensity (R)	1.6V	1.7v	1.8V
Low Current (R)	1.9V	2.3V*	2.7V*
High Efficiency (Y,G)	1.9V	2.2V	2.4V
High Intensity (Y,O)	1.7V	1.8V	2V
Low Current (G)	1.9V	2.1V*	2.3V*
Low Current (Y)	2.4V	3.1V*	3.5V*

* Pulsed mode only, max. cont. current: 7mA.

READERS SERVICES



ELEKTOR ELECTRONICS

FEBRUARY 1997

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Ready-made printed-circuit boards (PCBs), self-adhesive front panel foils, ROMs, EPROMs, PALs, GALs, microcontrollers and diskettes for projects which have appeared in *Elektor Electronics* may be ordered using the order form printed opposite. The form may also be used to order books (private customers only).

- Items marked with a dot (●) following the product number are in limited supply only, and their availability can not be guaranteed by the time your order is received.
- Items not listed here may not be available any more.
- The artwork for making PCBs which are not available ready-made through the Readers Services may be found in the relevant article.
- EPROMs, GALs, PALs, (E)PLDs, PICs and other microcontrollers are supplied ready-programmed.

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PAST ARTICLES

For information on past articles, please contact our Editorial and Administrative Office in Dorchester (telephone 01305 250995; fax 01305 250996).

Article title	Order no.	Price (£)	Price (US$)
FEBRUARY 1997			
Battery-Powered Preamplifier	960094-1	34.25	68.50
Motor Controller for R/C Models:			
- PCB and PIC16C84	960095-C	22.75	45.50
- PIC 16C84 only	966510-1	19.00	38.00
68HC11 Emulator:			
- PCB and diskette	970008-C	28.00	56.00
- Diskette only	976002-1	11.25	22.50
Simple Inductance Meter:			
- PCB and diskette	970009-C	15.25	30.50
- Diskette only	976001-1	8.75	17.50
Talking Doorbell	970015-1	10.50	21.00
CD-ROM Software Competition 1996/97 (compilation of all prize-winning entries). Disclaimer: software supplied *as is*, not tested by Elektor	976003-1	15.80	31.60
Mini LED Running-Lights		Not Available	
JANUARY 1997			
Dongle Switch	960089-1	7.00	14.00
Magnetic-Field Meter	960100-1	8.50	17.00
Speed regulator for Model Trains	960113-1	8.50	17.00
Monitor to Guard Fridge Temperature	970001-1	8.00	16.00
The Small Workshop:			
- component colour decoder software on disk	966022-1	10.00	20.00
CD-ROM Software Competition 1996/97 (compilation of all prize-winning entries). Disclaimer: software supplied as *is*, not tested by Elektor	976003-1	15.80	31.60
DECEMBER 1996			
20-bit A/D converter	960110-1	22.75	45.50
Remote Control by Visible Light	960068-1	11.00	22.00
Primary-Battery Refresher	960106-1	11.25	22.50
RS232 data acquisition card			
- PCB, PIC and disk	960098-C	35.50	71.00
- disk only	966019-1	7.25	14.50
- PIC 16C71 only	966508-1	24.00	48.00
Hands-On Electronics:			
- MicroCap V demo disks	966021-1	4.00	8.00
Electrically Isolated I²C bus	964062-1	6.75	13.50
Centronics I/O Port	964116-1	18.50	37.00
Mains Voltage Cleaner	964070-1	10.25	20.50
NOVEMBER 1996			
ST62 Programmer			
- PCB and disk	960105-C	16.75	33.50
- PCB only	960105-1	12.75	25.50
- disk only	966018-1	6.00	12.00
Hands-On Electronics:			
- MicroCap V demo disks	966021-1	4.00	8.00
Headphones Amplifier	960109-1	6.25	12.50
50W A.F. Amplifier	960079-1	8.00	16.00
Infra-red RS232 Link:			
- PCB and disk	960107-C	15.25	30.50
- disk only (Temic files)	966020-1	8.00	16.00
Steam-Engine-Noise-Generator	960087-1	7.75	15.50
OCTOBER 1996			
Video Test Chart Generator			
- PCB, EPLD, EPROM and disk	960076-C	79.50	159.00
- EPLD EPM7032	966507-1	39.00	78.00
- EPROM 27C040	966507-2	24.50	49.00
- Disk only	966011-1	7.00	14.00
Mini Flash Programmer:			
- PCB and software (disk)	960078-C	21.25	42.50
- Software only (disk)	966015-1	12.25	24.50
Mini Metal Detector	960075-1	5.50	11.00
Darkroom Timer	960086-1	11.75	23.50
Sampling Rate Converter:			
- PCB and ST62T10	960093-C	28.75	57.50
- ST62T10 (IC2)	966511-1	19.50	39.00
Thrifty Crystal Oven	960071-1	12.75	25.50
Electric-Bulb Tester	960091-1	6.00	12.00
Multi-Purpose Pascal I/O Unit (disk only)	966013-1	7.00	14.00
SEPTEMBER 1996			
Digital max/min thermometer:			
- PCB and ST62T10	960010-C	27.75	55.50
- ST62T10 (IC1)	956515-1	19.50	39.00
Standby Unit for TV Economy	960063-1	12.00	24.00
Digital Compass	960085-1	7.50	15.00
RS232 Interface for A/D Converter ICL7106:			
- software on disk	966016-1	6.00	12.00
JULY/AUGUST 1996			
Solar-Charging Regulator	930096	8.25	16.50
Continuity Tester	UPBS-1	1.95	3.90
Symmetrical Power Supply	UPBS-1	1.95	3.90
Harmonic Distortion Meter	936024-1	5.50	11.00
Sound-to-Light Unit	950123-1	9.50	19.00
50-MHz dBm Meter	964039-1	16.50	33.00
Precision Battery Capacity Meter	964040-1	8.00	16.00
Video Fader	964076-1	12.25	24.50
Inexpensive AD/DA Converter:			
- PCB	964092-1	Not Available	
- software on disk	966009-1	7.00	14.00
Single-Chip AF Power Amp	964104-1	6.25	12.50
JUNE 1996			
Flash EPROM Programmer/Emulator			
- PCB + disk	960077-C	33.00	66.00
- disk only	966017-1	16.00	32.00
Keyboard Swap for PCs	950126-1	7.00	14.00
Stop that Barking!	960035-1	5.50	11.00
23cm ATV preamplifier	960072-1	7.50	15.00
Pulsimeter	960005-1	10.25	20.50
Burglar Deterrent Lighting	960022-1	7.25	14.50
MAY 1996			
Intelligent Chess Clock:			
- PCB + 87C51 (946645-1)	950097-C	41.75	83.50
- 87C51	946645-1	30.75	61.50
Digital VU meter (2):			
- PCB + EPROM (946646-1)	950098-C	36.00	72.00
- EPROM 27C512	946646-1	17.75	35.50
Surround Sound Subwoofer (3):			
- PCB	960049-1	16.75	33.50
Mains Voltage Monitor:			
- PCB	960055-1	7.25	14.50
64-Channel Logic Analyser:			
- main PCB, disk & IC4,IC5	960033-C	69.75	139.50
- IC4 ispLSI1016	966506-1	27.50	55.00
- IC5 ispLSI1016	966506-2	27.50	55.00
- disk (MSDOS)	966010-1	7.00	14.00
- extension PCBs (3-in-1)	960033-2	17.00	34.00
- IC20/30/40 ispLSI1016	966506-2	27.50	55.00
APRIL 1996			
U2402B Battery Charger	950120-1	12.00	24.00
Centronics Interface:			
- PCB + disk (966008-1)	960052-C	16.25	32.50
- Disk (Windows)	966008-1	6.00	12.00
PC-Controlled AF Analyser (2):			
- Software on disk	966001-1	26.00	52.00
MARCH 1996			
Houseplant Buzzer (4 on 1 board)	950118-1	10.00	20.00
PIC-Controlled RDS Decoder:			
- PCB + PIC (966505-1)	960050-C	27.50	55.00
- PIC 16C84	966505-1	22.75	45.50
FEBRUARY 1996			
SIMM tester			
- PCB + EPROM (966503-1)	960039-C	28.25	56.50
- EPROM	966503-1	10.25	20.50
I²C Interface for Centronics port:			
- PCB + disk (946202-1)	950063-C	20.25	40.50
- control software on disk	946202-1	12.25	24.50
Passive VU meter	950124-1	8.00	16.00
FM Receiver in SMT	936049	5.00	10.00
Icy Roads Warning	960029-1	6.00	12.00
JANUARY 1996			
SECAM-to-PAL Converter	950078-2	29.00	58.00
Copybit Inverter:			
- PCB + MACH/GAL	950104-C	44.00	88.00
- MACH/GAL	956513-1	35.25	70.50
Passive Component Tester			
- PCB	960032-1	13.75	27.50
- Front panel foil		Not available	
DECEMBER 1995			
3.3-15V Power Supply	950106-1	9.25	18.50
Practice Amplifier for Guitars			
PCB + front panel foil	950016-C	30.50	61.00
PCB only	950016-1	17.25	34.50
Front panel foil only	950016-F	13.75	27.50
Smart Transistor Tester:			
- PCB + PIC (956502-1)	950114-C	44.25	88.50
- PIC 16C71	956502-1	35.50	71.00
Micro PLC System:			
- PCB + 87C750/51 + disk	950093-C	44.50	89.00
- 87C750/51	956514-1	24.50	49.00
- control software on disk	956016-1	10.00	20.00
Active potentiometer	954099-1	9.50	19.00
Descaler	954080-1	5.75	11.50
Active probe	954093-1	8.00	16.00
Two-way PC-Fax Interface	954033	11.75	23.50
NOVEMBER 1995			
PIP Processor:			
- PCB + 87C51 (956505-1)	950078-C	54.75	109.50
- 87C51	956505-1	30.75	61.50
FM noise squelch	950089-1	10.75	21.50
PA 300 power amplifier	950092-1	19.75	39.50
Jogging LED	950112-1	7.00	14.00
Oscilloscope prescaler	950115-1	27.75	55.50
OCTOBER 1995			
MatchBox BASIC computer:			
- PCB, 87C51, disk and Quick Reference Card	950011-C	59.25	118.50
- 87C51	956508-1	43.50	87.00
- Course diskette (DOS)	956009-1	11.50	23.00
- Quick Reference Card	950011-P	3.25	6.50
Special Autumn Supplement:			
- Experimentation board for PICs, incl. free disk for *PLC Emulation Using PIC Microcontrollers*	944105-1	17.75	35.50
SEPTEMBER 1995			
Hi-Fi headphone amplifier	950064-1	5.00	10.00
Dongle safe:			
- PCB	950069-1	12.75	25.50
- GAL IC2 (20V8)	956511-1	10.00	20.00
- GAL IC6 (22V10)	956512-1	11.75	23.50
HexFET power amp upgrade:			
- amplifier PCB	930102	12.75	25.50
- power-on delay PCB	924055	6.45	12.90
Copybit eliminator update:			
- PCB + MACH (956504-1)	950084-C	40.50	81.00
- MACH IC	956504-1	36.50	73.00
RF tone-dip oscillator	950095-1	5.25	10.50
JULY/AUGUST 1995			
Active mini subwoofer	936047	12.25	24.50
Mini robot car	936069	8.00	16.00
Simple RF function generator	950023-1	7.50	15.00
Alkali/Manganese battery charger	950065-1	6.75	13.50
Fast charger for NiCd batteries:			
- PCB - ST62T20 (956509-1)	950076-C	22.75	45.50
- ST62T20	956509-1	14.75	29.50
Simple I/O card	954074-1	11.50	23.00
6-V motive battery charger	940083-1	7.25	14.50
JUNE 1995			
Function generator:			
- PCB	950068-1	29.50	59.00
- Front panel foil	950068-F	17.75	35.50
Electronic sandglass:			
- PCB + 87C751 (946647-1)	950052-C	26.25	52.50
- 87C751	946647-1	17.75	35.50
Auto light control	950050-1	4.75	9.50
VGA distribution amplifier	950017-1	10.00	20.00
MAY 1995			
MIDI analyser:			
- PCB + EPROM (956507-1)	940020-C	34.25	68.50
- EPROM	956507-1	16.75	33.50
Programmer for 87/89C51 series Flash controllers:			
- PCB + EPROM (956644-1)	950003-C	26.50	53.00
- EPROM	946644-1	14.50	29.00
Programmable sine wave generator:			
- PCB + disk (956005-1)	950004-C	19.50	39.00
- control software on disk	956005-1	12.25	24.50
NiCd battery-quality tester:			
- PCB + ST62T15 (956506-1)	950051-C	25.25	50.50
- ST62T15	956506-1	18.25	36.50
APRIL 1995			
Electronic barometer	936033	8.50	17.00
Bat detector	936046	10.25	20.50
Sun blind control	950035-1	9.25	18.50
Function generator:			
- PCB + front panel foil	950044-C	21.75	43.50
- PCB	950044-1	11.00	22.00
- Front panel foil	950044-F	12.50	25.00
Stepper motor control:			
- PCB + 8751 + disk	950038-C	50.75	101.50
- 8751	956503-1	35.25	70.50
- test program on PC disk	956004-2	3.75	7.50
MARCH 1995			
Telephone-controlled mains switch:			
- PCB + PIC (946642-1)	950010-C	22.00	44.00
- PIC 16C54	946642-1	17.50	35.00
DSP function generator:			
- PCB + disk (956001-1) + EPROM (956501-1)	950014-C	49.00	98.00
- EPROM 27C512	956501-1	13.25	26.50
- software on IBM PC disk	956001-1	18.50	37.00
- Windows program manual	950014-P	7.50	15.00
TDA1560Q car audio amplifier	950024-1	9.50	19.00
FEBRUARY 1995			
MIDI multiplexor	930101	15.00	30.00
Automatic lighting timer	940098-1	10.75	21.50
Infrared dimmer	940109-1	9.75	19.50
Light-effects generator	940100-1	6.50	13.00
Upgrade your car battery charger	940111-1	7.00	14.00
Surround sound processor	950012-1	18.75	37.50
Induction motor governor	940095-1	7.50	15.00
JANUARY 1995			
Mini Audio DAC	940099-1	14.75	29.50
1-to-3-phase converter:			
- PCB + GAL + EPROM	940077-C	52.75	105.50
- GAL	946640-1	12.25	24.40
- EPROM	946640-2	15.75	31.50
P.O.S.T. diagnostic card:			
- PCB + GALs (946639-1/2)	950008-C	29.25	58.50
- GAL-1	946639-1	11.00	22.00
- GAL-2	946639-2	13.00	26.00
Self-loading EEPROM type X88C64 SLIC	940116-1	8.25	16.50
Debugging 8031/8051 microcontroller systems:			
- PCB + disk (946203-1)	940117-C	15.00	30.00
- software on IBM PC disk	946203-1	11.50	23.00
DECEMBER 1994			
In-car audio amplifier (3)	940078-2	30.25	60.50
RF immune power supply	940054-1	9.00	18.00
ispStarter kit from Lattice:			
- PCB + disk (946204-1)	940093-C	21.50	43.00
- Examples on PC disk	946204-1	9.75	19.50
NOVEMBER 1994			
Single-wire communication	940055-1	4.00	8.00
In-car audio amplifier (2)	940078-2	30.25	60.50
Solid-state disk:			
- PCB + EPROM (946641-1)	940085-C	47.50	95.00
- EPROM 27256	946641-1	23.50	47.00
Simple capacitance meter	940091-1	10.00	20.00
OCTOBER 1994			
Motive-battery charger	940083-1	7.25	14.50
Integrated AF amplifier:			
- output amplifier board	936062-1	9.50	19.00
- preamplifier PCB	936062-2	28.25	56.50
Tester for IR remote control	940084-1	6.50	13.00
In-car audio amplifier (1)	940078-1	14.00	28.00
TV line monitor:			
- PCB + PIC (946643-1)	940065-C	26.25	52.50
- PIC 16C54	946643-1	20.25	40.50
SEPTEMBER 1994			
Switchable a.c. supply	934004	6.50	13.00
Compact frequency meter	940051-1	9.00	18.00
Revolution counter:			
- sensor board (option)	940045-1	6.00	12.00
- main board	940068-1	5.50	11.00
JULY/AUGUST 1994			
General purpose IR volume control	930099	9.00	18.00
IR controlled switch	936066	9.75	19.50
MIDI swell pedal:			
- PCB + EPROM (946635-1)	940019-C	26.75	53.50
- EPROM 27C64	946635-1	13.75	27.50
Charge meter	940033-1	5.75	11.50
Joystick-to-mouse adaptor	944040-1	7.00	14.00
Centronics I/O interface	944067-1	8.75	17.50
80C451 controller board	944069-1	15.00	30.00
Robust AF power amp	944075-1	9.75	19.50
PC over-temperature alarm	944076-1	4.25	8.50

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Article title	Order no.	Price (£)	(US$)
1-4 MByte SIMM adaptor	944094-1	15.50	31.00
Optical doorbell	944080-1	6.25	12.50
PIC experimenting board	944105-1	17.75	35.50
RC5 transmitter with 80C535:			
- PCB + disk (946199-1)	944106-C	13.00	26.00
- software on IBM PC disk	946199-1	9.75	19.50
Small loop antennas:			
- software on IBM PC disk	1951	10.75	21.50
Software emulation of RC5 infra-red code:			
- software on IBM PC disk	1901	10.75	21.50
PIC programming course:			
- files and misc. utilities on IBM PC disk	946196-1	9.75	19.50
JUNE 1994			
80C535 SBC extension:			
- software on IBM PC disk	1941	9.75	19.50
- I²C display software on IBM PC disk	946197-1	9.75	19.50
I²C bus booster	940057-1	7.25	14.50
RS485 interface	940035-1	6.25	12.50
Fuel consumption monitor	940045-1	6.00	12.00
Intelligent EPROM eraser	940058-1	9.00	18.00
MAY 1994			
Mains signalling system - 2:			
- transmitter PCB, disk (1911) and EPROM (6371)	940021-2C	33.25	66.50
- EPROM 27C64	6371	13.25	26.50
- software on IBM PC disk	1911	9.75	19.50
APRIL 1994			
Mains signalling system - 1:			
- receiver board	940021-1	10.25	20.50
68HC11 processor board	930123	7.75	15.50
Headphones amplifier	940016	18.75	37.50
MARCH 1994			
80C535 assembler course:			
- EMON52 EPROM + disk (set)	6221	17.05	34.10
- disk only (IBM PC format)	1811	8.80	17.60
- EMON52 EPROM only	956517-1	12.80	25.60
100W AF amplifier			
- adaptor board	930039	8.25	16.50
FEBRUARY 1994			
80C535 single-board computer	924046	14.10	28.20
Copybit eliminator:			
- PCB + MACH + GAL	930098-C ●	46.25	92.50
- MACH + GAL	6321	42.25	84.50
Mini preamplifier	930106	29.25	58.50
Bidirectional RS232-to-Centronics converter	930134	14.00	28.00
JANUARY 1994			
SIM — an 8051 simulator:			
- software on IBM PC disk	1931	34.25	68.50
Digital dial	920161	12.75	25.50
RDS decoder			
- PCB + EPROM (6331)	930121-C	23.75	51.50
- EPROM 27C64	6331	14.50	29.00
I²C tester:			
- PCB + GAL (6341)	930128-C	36.25	72.50
- GAL type 6001	6341	30.75	61.50
Telephone-controlled switch:			
- EPROM 2764	6271	14.50	29.00
DECEMBER 1993			
535 card with EPROM emulator:			
- GAL and PAL	6311	26.00	52.00
RMS AF voltmeter:			
- PCB	930108	12.25	24.50
- front panel foil	930108-F	17.25	34.50
I²C power switch	930091	6.25	12.50
Medium power HEXFET amplifier	930102	12.75	25.50
Microcontroller-driven UART:			
- PCB	930073	4.75	9.50
- ST62T10	7151	17.25	34.50
SCART switching box	930122	14.25	28.50
NOVEMBER 1993			
Precision clock for PCs:			
- PCB + disk (1871)	930058-C	12.25	24.50
- software on IBM PC disk	1871	8.50	17.00
VHF/UHF TV tuner			
- PCBs -1 and -2 and μC 87C51 (7141)	930064-C	57.25	114.50
- μC 87C51	7141	25.75	51.50
Output amplifier with AF bandpass filter	930071	6.75	13.50
Digital hygrometer:			
- PCB + EPROM (6301)	930104-C	28.00	56.00
- EPROM 2764	6301	14.50	29.00
Power MOSFET tester	930107	32.50	65.00
OCTOBER 1993			
Stereo mixer	UPBS-1	1.95	3.90
MIDI channel monitor	930059	14.00	28.00
Ah meter with digital display	930068	14.00	28.00
Autoranging frequency readout	930034	12.50	25.00
ROM-gate switchover for Atari ST	930005	30.25	60.50
Microntroller-driven NiCd battery charger			
- board and ST62E15	920162-C	25.50	51.00
- ST62E15	7071	10.00	20.00
Fuzzy logic multimeter - 2:			
- PCB + Fuzzy Control One	920049-C	23.75	47.50
- Fuzzy Control One disk	1721	7.75	15.50
SEPTEMBER 1993			
Fuzzy logic multimeter -1	920049-2	20.00	40.00
Linear temperature gauge	920150	7.05	14.10
PC-aided transistor tester:			
- PCB	920144	9.75	19.50
- software on IBM PC disk	1781	7.50	15.00
Harmonic enhancer	930025	13.50	27.00
I²C alphanumerical display:			
- PCB + disk (1851)	930044-C	14.25	28.50
- Software on IBM PC disk	1851	8.50	17.00
Mini micro clock			
- PCB	930055	7.50	15.00
- clock: ST62T15	7111	11.50	23.00
- darkroom timer: ST62T15	7121	11.50	23.00
- cooking timer: ST62T15	7131	11.50	23.00
950-1750 MHz converter	UPBS-1	1.95	3.90
JULY/AUGUST 1993			
Active 3-way loudspeaker system	930016	21.50	43.00
Maxi micro clock			
- PCB	930020	15.50	31.00
- clock: ST62T10	7081	11.50	23.00
- darkroom timer: ST62T10	7091	11.50	23.00
- cooking timer: ST62T10	7101	11.50	23.00
SMD soldering station	930065	9.50	19.00
VHF-low converter	926087	15.50	31.00
I²C bus fuse (5 on 1 PCB)	934016	8.00	16.00
Voice operated recording	934039	6.00	12.00
General transformer PCB	934004	6.50	13.00
Plant humidity monitor	934031	4.50	9.00
Plant humidity monitor (supply)	934032	4.00	8.00
Four-fold DAC card for PCs:			
- GAL	6251	10.75	21.50
Multi-purpose display decoder:			
- EPROM 27128	6261	11.50	23.00
JUNE 1993			
Spectrum VU meter	920151	13.00	26.00
GAL programmer upgrade			
- PCB	930060	4.50	9.00
- software on IBM PC disks	1701	11.15	22.30
- idem, w/o Opal Jr. disks	1881	10.75	21.50
- software on Amiga disk	1841	11.00	22.00
Digital frequency readout for VHF/UHF receiver	926001-2	11.50	23.00
Inexpensive phase meter:			
- main board	930046	9.00	18.00
- meter board	920018	4.70	9.40
- front panel foil	930046-F	17.25	34.50
X2404-to-8751 interfacing:			
- software on IBM PC disk	1891	8.50	17.00
MAY 1993			
Philips preamplifier:			
- PCB	930003	7.50	15.00
- software on IBM PC disk	1861	8.50	17.00
APRIL 1993			
Audio power meter	930018 ●	10.25	20.50
Video digitizer for PCs:			
- PCB + disk (1831)	930007-C ●	37.00	74.00
- Software on IBM PC disk	1831	14.50	29.00
Infrared receiver for 80C32 single-board computer:			
- PCB and disk (1791)	920149-C ●	14.50	29.00
- software on IBM PC disk, also for DTMF decoder	1791	7.50	15.00
4MB printer buffer card:			
- PCB	920009 ●	27.50	55.00
- EPROM 27C64	6041	15.30	30.60
- front panel foil	920009-F ●	8.25	16.50
MARCH 1993			
Linear sound pressure meter	930006 ●	7.00	14.00
Electrically isolated RS232 interface	920138 ●	10.25	20.50
TV test pattern generator for 8032 SBC:			
- EPROM 27256	6151	15.30	30.60
FEBRUARY 1993			
Digital audio/visual system (4):			
- software package, EPROM, GALs and IBM PC disk	6181	30.50	61.00
U2400B NiCd battery charger:			
- PCB	920098 ●	8.75	17.50
- front panel foil	920098-F ●	8.75	17.50
Digital-audio enhancer	920169 ●	14.25	28.50
I²C opto/relay card:			
- PCB	930004 ●	11.00	22.00
- software on IBM PC disk	1821	7.65	15.30
Watt-hour meter:			
- PCBs -1 and -2, and EPROM (6241)	920148-C ●	37.25	74.50
- EPROM 27256	6241	10.00	20.00
DECEMBER 1992			
1.2 GHz multifunction frequency meter:			
- PCB + EPROM (6141)	920095-C ●	29.40	58.80
- EPROM 27C256	6141	11.45	22.90
- front panel foil	920095-F ●	13.80	27.60
Output amplifier for ribbon loudspeakers	920135-1 ●	19.40	38.80
	920135-2 ●	7.95	15.90
Peak-delta NiCd charger	920147 ●	4.10	8.20
Mains power-on delay	924055 ●	6.45	12.90
NOVEMBER 1992			
Difference thermometer	920078 ●	5.30	10.60
Low-power TTL-to-RS232			
interface	920127 ●	3.55	7.10
OCTOBER 1992			
Wideband active antenna	924101 ●	3.25	6.50
RDS demodulator	880209 ●	5.30	10.60
Pascal routines for Multi-function Measurement Card for PCs: software on disk	1751	9.70	19.40
SEPTEMBER 1992			
EPROM emulator - II:			
- PCB	910082 ●	10.00	20.00
- Software on IBM PC disk	129	6.75	13.50
JULY 1992			
12VDC to 240VAC inverter			
- main board	920039-1 ●	11.15	22.30
- power board	920039-2 ●	6.45	12.90
- front panel foil	920038-F ●	16.15	32.30
JUNE 1992			
I²C display	920004 ●	4.70	9.40
Guitar tuner:			
- PCB	920033 ●	10.00	20.00
- front panel foil	920033-F ●	8.80	17.60
Multi-purpose Z80 card	920002 ●	20.25	40.50
- GAL set (2x16V8)	6111	11.15	22.30
- BIOS EPROM 27128	6121	15.30	30.60
- software on IBM PC disk	1711	7.65	15.30
May 1992			
GAL programmer:			
- PCB	920030 ●	11.15	22.30
- software: see June 1993			
APRIL 1992			
80C32 SBC extension	910109 ●	13.50	27.00
2-metre FM receiver	910134 ●	10.30	20.60
Automatic NiCd charger	UPBS-1	1.95	3.90
LCD for L-C meter	920018 ●	4.70	9.40
MARCH 1992			
8751 emulator	920019 ●	12.05	24.10
- EPROM 27C64 + IBM disk	6051	29.40	58.80
A-D/D-A and I/O for I²C bus:			
- PCB	910131-2 ●	6.15	12.30
- software on IBM PC disk	1821	7.65	15.30
FEBRUARY 1992			
8051/8032 assembler course:			
- EMON51 EPROM + course disk for IBM PCs (1661)	6061	20.00	40.00
- EMON51 EPROM + course disk for Atari (1681)	6091	20.00	40.00
- course disk for IBM PCs	1661	7.65	15.30
- course disk for Atari	1681	7.65	15.30
JANUARY 1992			
Mini Z80 system	910060 ●	10.60	21.20
Prototyping board for IBM PCs	910049 ●	21.15	42.30
PC-controlled weather station (3):			
- software on IBM PC disk (supersedes 1551 and 1561)	1641	7.65	15.30
DECEMBER 1991			
Class-A power amplifier (2):			
- protection PCB	880092-3 ●	7.50	15.00
- power supply PCB	880092-4 ●	7.60	15.20
Connect-4 software in 2764 EPROM	6081	15.30	30.60
NOVEMBER 1991			
Relay card for universal I/O interface	910038 ●	12.95	25.90
Class-A power amplifier (1):			
- voltage amp. PCB	880092-1 ●	9.95	19.90
- current amp. PCB	880092-2 ●	9.05	18.10
Timer for CH systems	UPBS-2	3.80	7.60
24-bit full-colour video digitizer (extension for Archimedes project):			
- software on Arch. disk	1631	11.15	22.30
OCTOBER 1991			
Audio spectrum shift encoder/decoder	910105 ●	10.35	20.70
SEPTEMBER 1991			
Plotter driver:			
- software on IBM PC disk	1541	11.15	22.30
JULY/AUGUST 1991			
Multifunction I/O for PCs:			
-PCB	910029 ●	24.40	48.80
- PAL 16L8	5991	8.25	16.50
B/W video digitizer:			
- PCB	910053 ●	22.60	45.20
- software on Arch. disk	1591	11.15	22.30
Stepper motor board - 2:			
- power driver board	910054-2 ●	28.50	57.00
JUNE 1991			
Universal battery charger	900134 ●	9.40	18.80
Digital phase meter (set of 3 PCBs)	910045-1/2/3 ●	26.15	52.30
Light transceiver	UPBS-1	2.30	4.60
Variable AC PSU:			
- PCB	900104 ●	6.15	12.30
- front panel foil	900104-F	16.45	32.90
Light switch with TV IR r/c	910048 ●	5.60	11.20
Real-time clock for Atari ST:			
- PCB	910006 ●	6.15	12.30
- software on IBM PC disk	1621	7.65	15.30
Stepper motor board -1:			
- PAL 16L8	6011	8.25	16.50
MAY 1991			
80C32/8052 Computer	910042 ●	12.05	24.10
Battery tester	906056 ●	4.10	8.20
Universal I/O interface for IBM PCs	910046 ●	10.85	21.70
APRIL 1991			
MIDI programme changer:			
- PCB	900138 ●	6.75	13.50
- EPROM 2764	5961	15.30	30.60
8-bit I/O for Atari:			
- PCB	910005 ●	12.35	24.70
Wattmeter			
- meter board	910011-1 ●	6.45	12.90
- display board	910011-2 ●	4.10	8.20
Tektronix/Intel file converter:			
- software on IBM PC disk	1581	7.65	15.30
Dimmer for halogen lights:			
- transmitter board	910032-1 ●	4.10	8.20
MARCH 1991			
The complete preamplifier:			
- input board	890169-1 ●	26.10	52.20
- main board	890169-2 ●	39.35	78.70
FEBRUARY 1991			
Multifunction measurement card for PCs:			
- PCB	900124-1 ●	28.20	56.40
- PAL 16L8	561	10.30	20.60
- software on IBM PC disk	1461	7.65	15.30
MIDI-to-CV interface:			
- 2764 EPROM	5981	15.30	30.60
RDS decoder:			
- demodulator board	880209 ●	5.30	10.60
- processor board	900060 ●	7.65	15.30
- EPROM 2764	5951	15.30	30.60
NOVEMBER 1990			
Medium-power audio amplifier	900098 ●	10.60	21.20
Programmer for the 8751			
- PCB	900100 ●	8.25	16.50
- μC 87C51	7061	46.40	92.80
- software on IBM PC disk	1471	7.65	15.30
JULY/AUGUST 1990			
Compact 10A power supply	900045 ●	13.50	27.00
Intermediate projects	UPBS-1	2.30	4.60
Mini FM transmitter*	896118 ●	5.00	10.00
Sound demodulator for satellite TV receivers	900057 ●	4.40	8.80
* can not be supplied to readers in the UK			
JUNE 1990			
Power zener diode	UPBS-1	2.30	4.60
MAY 1990			
Acoustic temperature monitor	UPBS-1	2.30	4.60
APRIL 1990			
Digital model train (13)	87291-10 ●	4.70	9.40
Q meter	900031 ●	7.05	14.10
RS-232 splitter	900017-1 ●	8.50	17.00
	900017-2 ●	5.30	10.60
MARCH 1990			
Digital model train (12)	87291-9 ●	4.10	8.20
FEBRUARY 1990			
Digital Model Train (11)	87291-8 ●	5.30	10.60
Reflex MW AM receiver	UPBS-1	2.30	4.60
JANUARY 1990			
Mini EPROM programmer	890164 ●	8.25	16.50
All solid-state preamplifier	890170-2* ●	18.50	37.00
The Digital Model train (10):			
- control program on disk	109	6.75	13.50
DECEMBER 1989			
Digital Model Train	87291-7 ●	10.30	20.60
Solid-state preamp	890170-1* ●	13.80	27.60
	890170-3* ●	10.60	21.20
NOVEMBER 1989			
Digital Model Train (8)			
- PCB	87291-5 ●	51.10	102.20
- EPROM 27C64	572	11.75	23.50

Availability of older items is advised by our Dorchester Office, tel. (01305) 250995, fax (01305) 250996